AGV & AMR Robotics, Nov 2023
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AGV & AMR ROBOTICS 2023

MOBILE ROBOTS IN FACTORY, PRODUCTION & WAREHOUSE ENVIRONMENTS | NOV 2023

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EXEC SUMMARY: POST PANDEMIC GROWTH SLOWING. US REMAINED STRONG. CHINESE COMPETITION AT BREAKING POINT. GLOBAL ORDERS IN 2024 MAY BE CHALLENGING

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DEFINITION: AGV & AMR ROBOTS

- Focus on mobile robots used to transport payloads (10Kg - 10s of tonnes) between A-B, deployed in factories, production facilities and warehouses *(excl. ecommerce applications – covered in G2P here)*

2023 MARKET GROWTH POSITIVE

- 52% of stakeholders indicated a positive 2023 and that a return to normal was to be expected after 'crazy growth' in 2022
- Key market drivers included the automotive sector (switch to electric vehicles), F&B and the US market
- Growth in Europe had largely dissipated in 2022

CHINA LARGELY COMMODITISED

- The Chinese market grew in 2023, but price competition had turned hyper-competitive with domestic prices for AGV & AMRs at historical lows
- Vendors with money left in the bank targeted a 2024 launch in the US market, partnering in the EU

SUPPLY CHAIN PROBLEMS ABATED

- Lead times returned to near normal whilst prices for components (and robots) increased about 10-30% in NA and EU during Covid

INHIBITORS FOR FASTER GROWTH

- The global AGV & AMR market has experienced around 10-15% annual growth in the last decade
- But there were multiple inhibitors for faster growth:
- Of 100 incoming inquiries, only 1 customer was fully aware of the need to change processes and workflows to accommodate robots; sector marketing thought to contribute to this
- A highly fragmented landscape with 500+ vendors = difficult for customers to select the right partner/s
- Some customisation in nearly every project
- Brownfield accounted for majority of sales, but was often complicated due to frequent re-engineering requirements, moving infrastructure, fixing floors
- Lack of established AGV/AMR system integrators

GROWING SOFTWARE IMPORTANCE

- AGV & AMR software innovation led by Agnostic Fleet Managers, catalysed by interop standards
- A "frenzy" of Agnostic Fleet Manager selection in 2023 had led to AGV & AMR project delays
- FMS evolving into "Intralogistics Operating Systems" with growing consulting opportunities/practice
- Other SW trends included 3D visualisation tools as a pre-sales tool, VSLAM for RTLS, etc.

MARKET OUTLOOK 2024 + BEYOND

- Stakeholder suggested it had become increasingly difficult to apply any forecasting methodologies
- The US market remained very strong, but elections in 2024 could bring additional volatility
- Multiple international vendors aimed to establish, consolidate and/or grow their US presence in 2024
- Increased offers of RaaS and/or Rental appeared to be early attempts at stimulating growth
- Continued M&A expected as some businesses may run out of cash and could be acquired; interviews suggested growing signs of distress in the sector

RECOMMENDATIONS TO BUYERS

- Senior management buy in – always
- Know your processes and workflows intimately and how these may be affected by a mobile robot
- Start small and learn from a few vehicles or go larger with throughput/ performance bonds

CONTENTS

GOLD SPONSORS

SAFELOG

MAG Mobile Automation Group powered by MHI

KOLLMORGEN
A REGAL REXNORD BRAND

AGV & AMR ROBOTS (IN THIS REPORT) REPRESENTED A PART OF THE LARGER MOBILE ROBOTICS ECOSYSTEM, FROM G2P SOLUTIONS TO AUTONOMOUS VEHICLES

AGV & AMR ROBOTS ON A SLIDING SCALE FROM G2P SOLUTIONS TO AUTONOMOUS DELIVERY VEHICLES (vehicle sizes not to scale)

Description (generic)

G2P SOLUTIONS

- Medium docking tolerances
- IP54 rating (indoor use only)
- Solid rubber tires
- Navigation tech Datametric, SLAM
- Primarily deployed in warehouse facilities
- Overlaps with other G2P solutions, such as ASRS Shuttles, etc;fFor more info on G2P, download STIQs G2P Solutions reports here

AGV & AMR ROBOTICS

- Lower docking tolerance
- In general <IP54 rating (indoor use only), but custom vehicles also operate outdoor (>IP54)
- Solid rubber tires
- Navigation tech Line Guidance, Reflectors, SLAM, Datametric, etc.
- Deployed in both production and warehouse facilities
- Overlaps with G2P Solutions and Yard/Port vehicles (the latter also includes custom made AGV & AMR vehicles)

YARD/ PORT VEHICLES

- Higher docking tolerance
- IP67 rating (outdoor/ any weather use)
- Solid rubber or other filled tires (air, foam, etc.)
- Navigation often mixture of SLAM, GNSS/GPS, RTK, Line Guidance, Reflector Guidance
- Restricted area/ private ground operations

DELIVERY VEHICLES

- Higher docking tolerance
- IP67 rating (outdoor/ any weather use)
- Standard tires
- Navigation mixture of SLAM, GNSS/GPS, RTK
- Operates on public road and/or curbside
- For more info on autonomous delivery vehicles, download STIQs Autonomous Delivery Vehicle report here

Source: STIQ Ltd Research & Analysis

THREE PRIMARY AGV & AMR ROBOT FORM FACTORS: MOUSE, FORKLIFT, AND TUGGER

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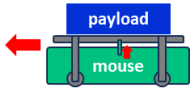
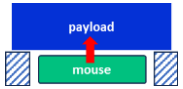
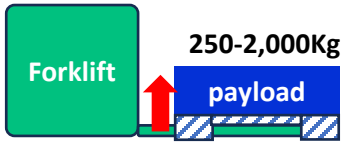
THREE PRIMARY FORM FACTORS IN THE AGV & AMR ROBOTICS SECTOR

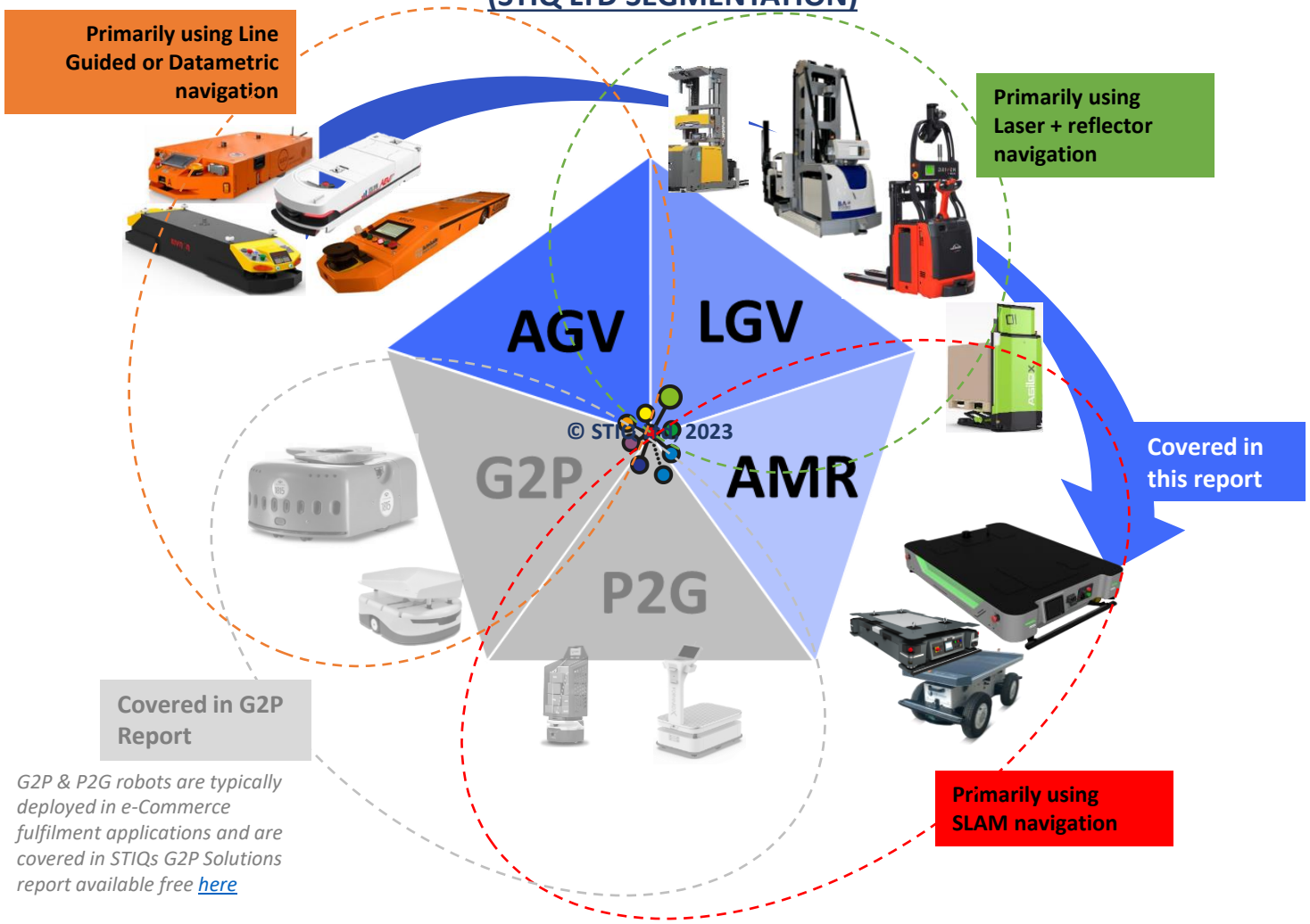
	Photo, Illustration of payload	Primary Functionality	General Commentary
MOUSE	*Versatility: ↑*  **Tugger: 500Kg-**  **Lift: 50-1,500Kg**  	• A Mouse robot drives under payloads and attaches or lifts from below (also known as Turtle) • Additional infrastructure may be required to deploy mouse robots, i.e. a pallet may have to rest on a stand for a mouse vehicle to drive under and lift it • Conveyors, lifts or pins/hooks that attach to a trolley from below are the primary attachments with mouse vehicles	• The mouse vehicle is the most versatile of all AGV & AMR Robotics form factors and can be applied to nearly any application and payload with some modification • Can be fitted with various tools, fittings, mechatronics, etc. on top of the vehicle • Payloads are unlimited, but over 1.5-2t are primarily bespoke vehicles
FORKLIFT	*Versatility: →*   	• Autonomous forklifts can be dedicated trucks or converted manual forklifts • Payloads need to be forklift ready or rest on a pallet • There are two primary types of pallets: open and closed. Counterbalance forklifts can manage both types whilst some other forklifts can only work with open pallets	• Autonomous forklifts are frequently converted from manual forklifts and come in a wide range of lift heights and depths, etc. • Forks can be exchanged for specialist tools for lifting metal coils, paper rolls, etc. • Payloads tend to be max 1.5-2tons
TUGGER	*Versatility: ↓*  **500-10,000Kg**  	• A tugger typically pulls a train of trolleys or carts each containing a payload • Frequently used in so-called 'milkruns' (source info on milkruns) in automotive manufacturing • Often require manual activity to load payloads on/off each trolley/cart	• Tuggers are frequently converted from manual vehicles • Payloads tend to be in multiples of tons • Mouse vehicles may also be converted to tuggers, typically for lower payloads and for individual trollies rather than trains

Source: STIQ Ltd Research & Analysis

Key: *Direction of movement* *Payload* *Vehicle chassis* *Additional infrastructure*

‘INTRALOGISTIC MOBILE ROBOTS’ OVERLAP IN APPLICATIONS, FUNCTIONALITY AND NAVIGATION TECHNOLOGY. CLEAR SEGMENTATION INCREASINGLY DIFFICULT

MOBILE ROBOTS IN MATERIAL HANDLING APPLICATIONS (STIQ LTD SEGMENTATION)



G2P & P2G robots are typically deployed in e-Commerce fulfilment applications and are covered in STIQs G2P Solutions report available free here

STIQs SEGMENTATION - INTRALOGISTICS

- STIQ divides the Intralogistics mobile robotics sector into five different segments using a combination of navigation technology and primary application
- AGV – Line guided vehicles
- LGV – Laser guided vehicles, typically forklifts
- AMR – SLAM navigated vehicles
- P2G – SLAM navigated vehicles deployed in ‘eaches picking’ applications combined with manual pickers/operators; ecommerce primary application
- G2P – Datametric navigated vehicles, Kiva/Amazon Robotics-type robots, ecommerce primary application

AGV + LGV + AMR IN THIS REPORT

- AGV, LGV and AMR vehicles are all covered in this report
- P2G and G2P vehicles were covered in STIQs G2P Solutions report (download free here) focused on ecommerce/‘eaches picking’ applications

OVERLAPPING/ MERGING SEGMENTS

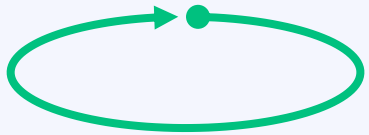
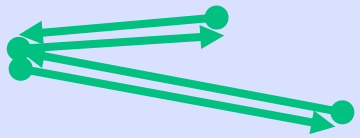
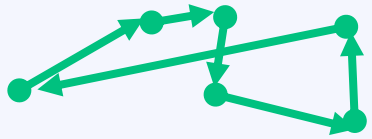
- Mobile robots and navigation technologies are increasingly applied to many different use cases and industries and there is a growing diffusion between segments
- For example, Datametric or QR code robots have been increasingly deployed in industrial applications, competing with line guided AGVs

Source: STIQ Ltd Research & Analysis

AGV & AMR ROBOTS COVERED IN THIS REPORT WERE PRIMARILY DEPLOYED TO TRANSPORT GOODS IN THREE MAIN TYPES OF MISSIONS

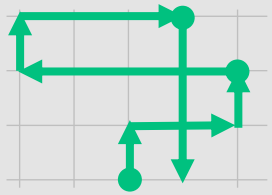
AGV & AMR ROBOTICS APPLICATIONS, TASKS, VEHICLES, MOVEMENT PATTERNS AND VEHICLE FORM FACTORS

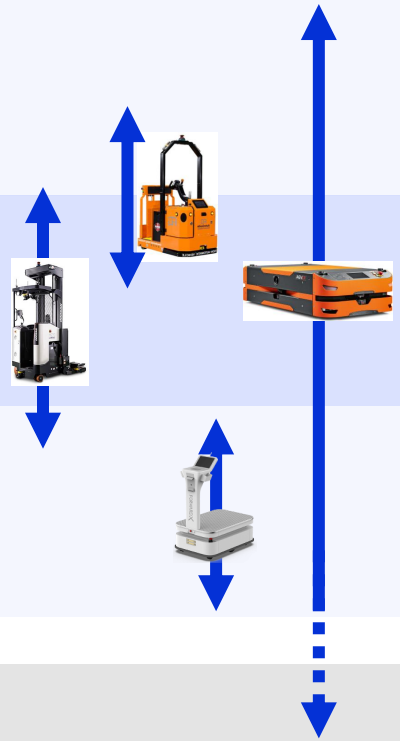
Primary AGV & AMR missions

AGV & AMR Application	Application Description	Typical Vehicle Mission Movement Pattern (simplified)	Movement/ Mission Description	Sample Vehicle Form Factor Deployed
ASSEMBLE	• Example: A chassis is placed on the mobile robot moving across stations on a production line		• Circular pattern, occasionally with staging posts and/or conditional choices	
MOVE	• Example 1: Moving a payload, such as a pallet, from the end of a production line into warehouse racking • Example 2: Milkround; moving parts throughout a factory, feeding into production activity		• Multi-stage and/or conditional options based on single instruction order	
PICK	• Example 1: Robot is sent to a warehouse location to wait for a manual worker to pick a case and place on the robot and instruct for next action • Example 2: Supermarket type applications and/or wholesale picking		• Chaos pattern with multiple staging instructions	

Pick applications overlap with Ecommerce (G2P/ P2G) applications - covered in STIQs G2P Solutions reports

Emerging mission

ECOMMERCE	• Example: Robots operate in a matrix environment and pick up/drop off storage pods placed on each crossing. Robots bring storage pods to pick locations for (mainly) manual picking but also increasingly automatic unload/loading in factory environments		• Matrix pattern with 90/180/270/360° turning on Fiducials (QR/Datametric code on the floor) • Collect, deliver, and return missions • Typically fenced off from people	

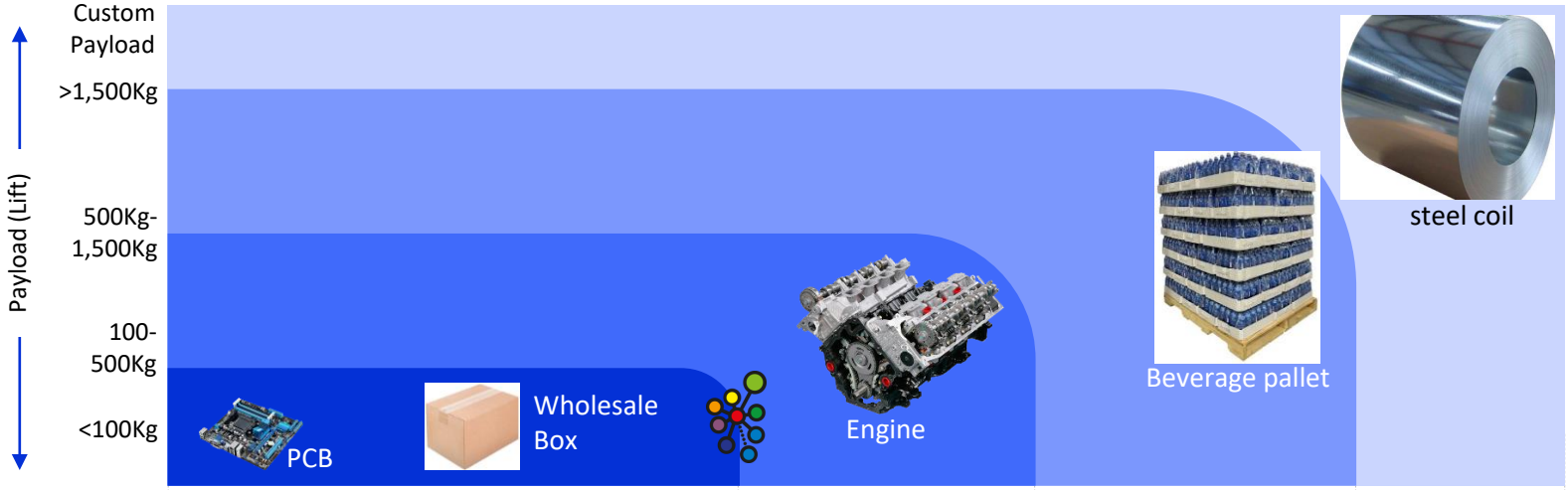


Source: STIQ Ltd research & analysis

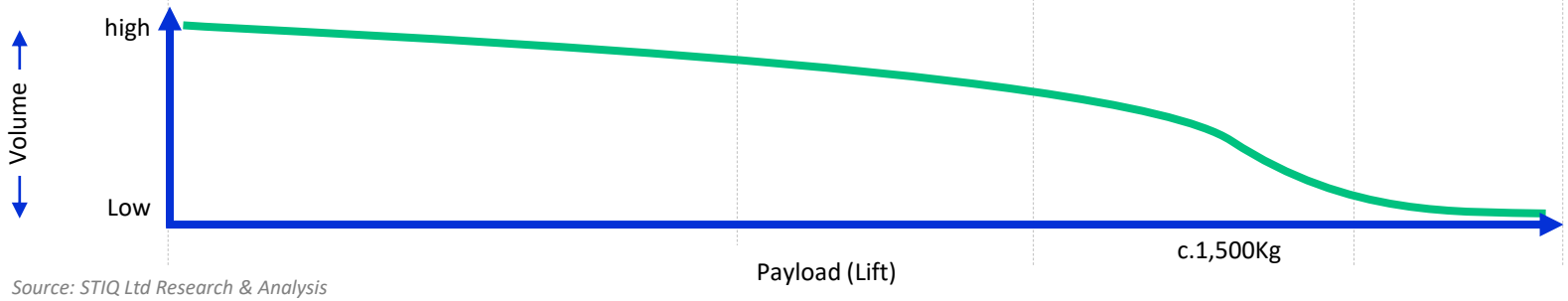
Key: Staging + movement Movement

PAYLOADS VARY ENORMOUSLY FOR AGV & AMR ROBOTS, FROM HANDLING SEMICONDUCTOR CHIPS TO TRANSPORTING 10's TONS METAL COILS

SAMPLE APPLICATIONS AND PAYLOADS FOR AGV & AMR ROBOTS



AGV & AMR ROBOT VOLUME INDICATOR BY PAYLOAD



Source: STIQ Ltd Research & Analysis

LIFTING V TOWING

- This analysis focuses on lifting payloads as towed payloads were generally higher than for lifted payloads
- There was a kind of natural cut off for higher volume vehicles at 1,500Kgs as this tend to be the weight of a full single drinks pallet
- AGV & AMR vehicles above 1.5-2t tended to be custom made, but some companies had attempted to serialise production at higher payloads

LOWER PAYLOAD, HIGHER VOLUME

- The volume/ quantity of robots sold was inversely related to the payload, i.e. the smaller the payload, the more vehicles were deployed
- This was also related to the cost of vehicles where lower cost vehicles were sold in higher quantities

MANUAL HANDLING/MANUALLY OPERATED VEHICLES AND CONVEYORS: TWO PRIMARY COMPETING OPTIONS TO AGV & AMR ROBOTS

PRIMARY TRANSPORTATION OPTIONS – MANUAL, CONVEYOR, AGV & AMR ROBOTS

MANUAL HANDLING

CONVEYOR

AGV & AMR ROBOT

	MANUAL	CONVEYOR	AGV & AMR ROBOT
+	• High flexibility • Adjusts to different standard formats, such as closed and open pallets • Can easily switch tasks and vehicles from forklifts to tuggers and pump trucks (image)	• High reliability, well established product • Perfect for high volume movements with well-defined non-changing destinations • Can work continuously • Depreciates	• Adds redundancy (can remove one robot without shutting down whole line) • Can switch between multiple destinations, routes (flexibility) and payloads (may require re-engineering) • Space efficient (compared to conveyors) • Depreciates
-	• Can be prone to errors • Salaries (primarily) upwards only • Training can be extensive for some roles • Recruitment for more advanced roles such as forklift drivers can be difficult • Can be unreliable	• Inflexible – cannot be easily moved, reprogrammed, etc. • Requires some standardisation on payloads, items to be transported • High upfront costs • Ongoing maintenance costs • Only as strong as the weakest link	• Re-programming to different destination, routes, etc. can be tricky and may require an engineer on site • May require specialists and recruitment can be difficult • High upfront costs • Ongoing maintenance costs • May require software integration • Requires standardised payload formats (inflexible)

Source: STIQ Ltd Research & Analysis
Image source: Left, Middle, Right

AGV & AMR ROBOTS OFFER ADDITIONAL REDUNDANCY AND OPTIMISATION OPPORTUNITIES IN WAREHOUSE AUTOMATION SYSTEMS

AGV & AMRS VS CONVEYORS

- AGV & AMR Robots offer a more flexible approach compared to a conveyor solution and also offered many different opportunities for optimisation

"Customers can only simulate the throughput. But it's a simulated performance test. And what's the worst thing to happen in our scenario? Let's say it is a giant project and we have a buffer for the performance and we miscalculated the number of units, so instead of 100 units, we need 105. This risk is on our side. But if you have a conveyor system, it's really hard to change the throughput. But in an AGV system there's always room for changing the process. Rotating less, drive faster, take shortcuts… there's so much potential in optimization that we don't struggle with our performance goals." [SAFELOG]

- Using AGVs or AMRs instead of a conveyor adds redundancy to the system

"Let's say a customer is planning a new fulfillment center and they have System Integrator A as one of their bidders. It's possible that in some areas of the warehouse there will be two options for the transport of the pallet. It could be an AGV option, but there could also be a conveyor option. For the conveyor option, System Integrator A has to calculate a bigger buffer usually, because it's harder to change and you are kind of stuck. By using AGVs they now have a chance to be more precise because if you're off, it's pretty simple to fix the mistake… by adding more bots for example." [SAFELOG]

EXAMPLE OF CONVEYOR INSTALLATION

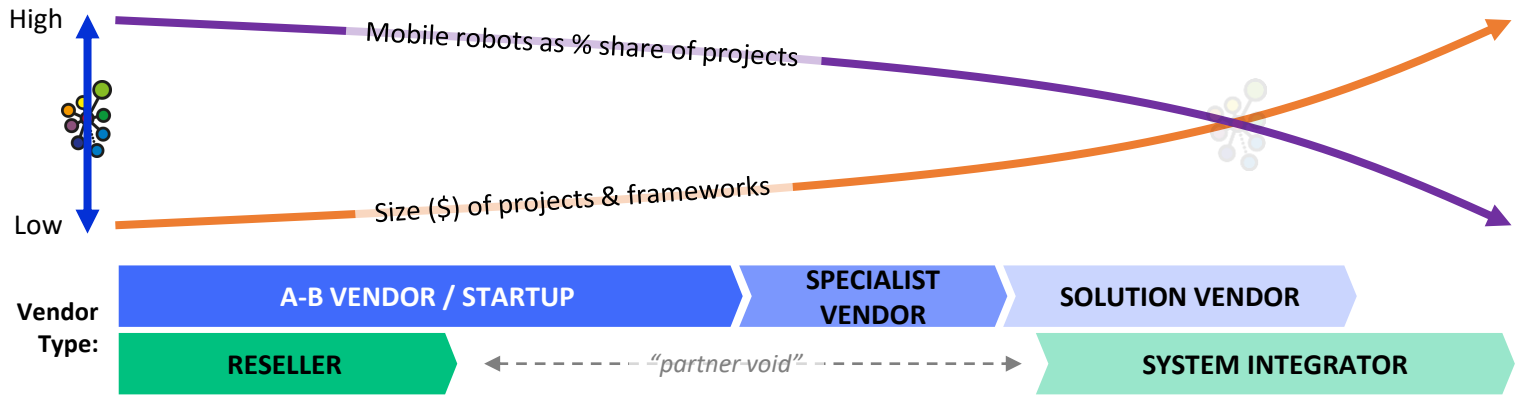
Image Source: Indiamart

AGV & AMRS VS CONVEYORS, CROSSING

- Using mobile robots can also provide more flexible crossing opportunities for people to walk across the line of transportation

AGV & AMR IS A RELATIVELY MATURE MARKET WITH MANY VENDOR TYPES, FROM STARTUPS TO SOLUTION VENDORS, OFTEN COMPETING IN DIFFERENT SEGMENTS

TYPES OF AGV & AMR ROBOTICS VENDORS AND DIFFERENCES (SIMPLIFIED)



Source: STIQ Research & Analysis

DIFFERENT VENDOR TYPES

- STIQ identified 5 primary types of AGV & AMR vendors
- Note this is a simplified segmentation that seeks to explain why, sometimes, vendors of seemingly similar equipment rarely compete

"When we talk about AGVs & AMRs and everything else that's under that umbrella… the market is so vast and there are so many opportunities out there. While many vendors are competitors, many times they are competing and working in completely different marketplaces." [E80 Group]

>> THE RESELLER/ DISTRIBUTOR

- Typically focuses on small projects with <5 robots which tend to be simple A-B transportation
- Companies vary from individual to Industrial Robot integrators with 100's of staff
- Staff often lack specialist workflow and/or process consulting expertise

>> THE A-B VENDOR/ STARTUP

- Frequently includes more recent AGV & AMR entrants, startups and companies 'dipping their toes' in the sector
- Most vendors have an agnostic sector approach
- Projects are often single units, but may occasionally grow to many 10's of vehicles, often for the more experienced vendors

>> SPECIALIST VENDOR

- Vendors with specialist knowledge and reputation in an industry vertical, such as automotive, batteries, renewables, retail, etc.
- Projects generally 10-50 vehicles, but can be 100's of vehicles with larger customers and may focus on a single function within a factory
- Fortunes of these vendors tend to go hand in hand with the vertical/s targeted
- Likely to have a team of process/workflow experts

>> SOLUTIONS VENDOR

- Projects can include automating a complete end of line warehouse, i.e. a solution outcome rather than a single system
- Mobile robots may account for 25-75% of a solution and vendors have tended to include autonomous forklift vehicles as a core system supported by conveyors, etc.
- Focus on a narrow set of industries, such as automotive and/or F&B often with multi-year framework agreements
- Increased focus on software and may offer WMS, WCS

>> SYSTEM INTEGRATOR

- Wider range of customer verticals when compared to Solutions Vendors
- Mobile robots often represent <25% of total projects
- Product portfolio ranges frequently include other systems, such as ASRS, stacker cranes, robot arms, etc. with a focus on software, such as WMS, WCS, WES, etc.

ANALYSIS OF PUBLIC AGV & AMR MARKET SIZE ESTIMATES HIGHLIGHTED THREE DISTINCT MARKET SIZE "CONSENSUS GROUPS" WITH SIMILAR FUTURE GROWTH INDICATIONS

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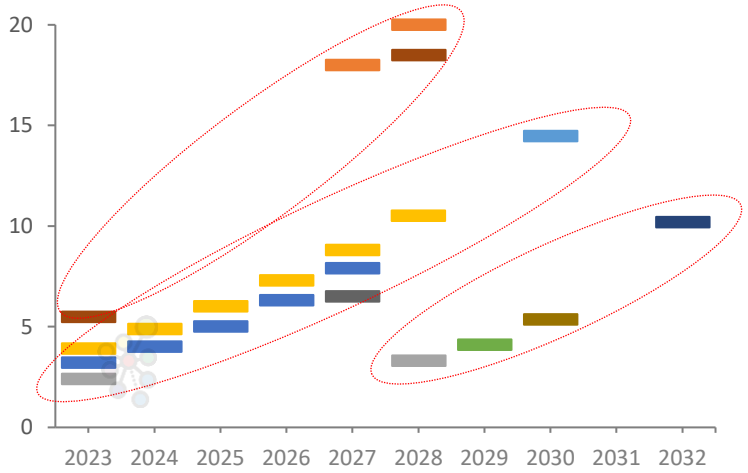
PUBLICLY AVAILABLE GLOBAL AGV & AMR MARKET SIZE ESTIMATES, 2023-2032 ($BN)



Source: Research & Markets, LogisticsIQ, Statista, Statzon/Market Research Future, Markets & Markets, Grand View Research, Inkwood Research, Fortune Business Insights, Mordor Intelligence, Interact Analysis, Verified Market Research. Most extracted from Google search

SIGNIFICANT DELTA IN MARKET SIZING

- There is significant discrepancy between market research vendors for the global AGV & AMR Robotics market
- In some cases, the market size varied by up to 6X

DEFINITIONS COULD BE THE DIFFERENCE

- The terms "AGV & AMR" remain vague and could potentially incorporate nearly any type of mobile robot including consumer robots such as floor cleaning and lawnmower bots

LARGER NUMBERS CAN HELP IN MARKETING

> The combined AGV and AMR market is estimated by industry experts to exceed $18 billion by 2027.

Source: Screenshot (source)

- STIQ defines AGV & AMR Robots as the products (hardware and software) covered in this report, or top left quadrant in the "AGV & AMR Market Definitions" chart – top right on this page

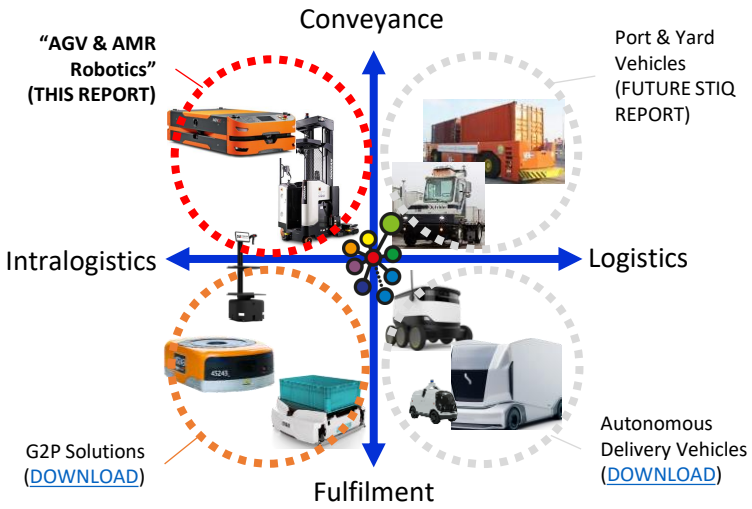
AMAZON MAY ALSO DISTORT NUMBERS

- Amazon was the world's largest manufacturer and user of mobile robots, not offered on the open market
- The vast majority of Amazon's robots use a single type of navigation, however, they were increasingly also deploying mobile robots with other types of navigation
- If Amazon's volumes are included in market sizing, they could be solely responsible for >80% of market share in certain segments

OTHER PERSPECTIVES

- The use case can also play into higher numbers, for example if a company is fundraising they may be prone to highlighting a larger TAM
- Market size vendors also have to market their goods and occasionally media outlets may prefer headlines with a very large number

AGV & AMR MARKET DEFINITIONS



Source: STIQ Research & Analysis
Note: All vehicles in the graphic could be considered "AGVs or AMRs"

SO WHAT IS THE ACTUAL MARKET SIZE?

- At STIQ we spend significant time talking to vendors, component suppliers and customers to get a view on market size and demand for the AGV & AMR Robotics sector
- STIQs data is clearly defined – see above "AGV & AMR Robotics" and segmented to industry standards. To inquire – contact Tom tom@styleintelligence.com
- Note STIQs market size data is a **fee-based product**

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NEW FACTORY AND WAREHOUSE CONSTRUCTION A MAJOR DRIVER OF GROWTH. AUTOMOTIVE SECTOR SWITCH FROM IC TO EV CURRENTLY A KEY DRIVER

TOP MARKET DRIVERS IN THE AGV & AMR ROBOTICS SECTOR

Driver	Description	Impact
New Factory and/or Warehouse Construction	• New factory + warehouse construction or refurbishments has a direct positive impact on AGV & AMR demand	↑
Automotive sector switch from IC to EV	• The global automotive sector continued its switch from combustion to EV production lines which has been a key demand driver	↑
Access to labour (lack of labour)	• Employment levels remained elevated, and companies continued to struggle with a limited talent pool - across customers and vendors • De-risking production was driving increased automation	↗
Price Increases (from Supply Chain disruption)	• Increased demand in 2021 & 2022 combined with supply chain disruptions meant some component suppliers delivery times extended beyond >52weeks • This also meant price increases of 10-30% • The effect on new sales growth occurred primarily during 2021 and 2022 with some orders being fulfilled in 2023 • Overall, the effect has been less nuanced in 2023 with no major impact on growth	→

CAVEAT FOR MARKET DRIVERS

- Note this report **excludes e-commerce applications**, such as Goods to Person pick solutions – covered in STIQs G2P Solutions reports (download here)
- Such e-commerce applications were more similar to AGV & AMR Solution Vendors where the end customer may care less about which robots are being deployed with a focus on actual throughput

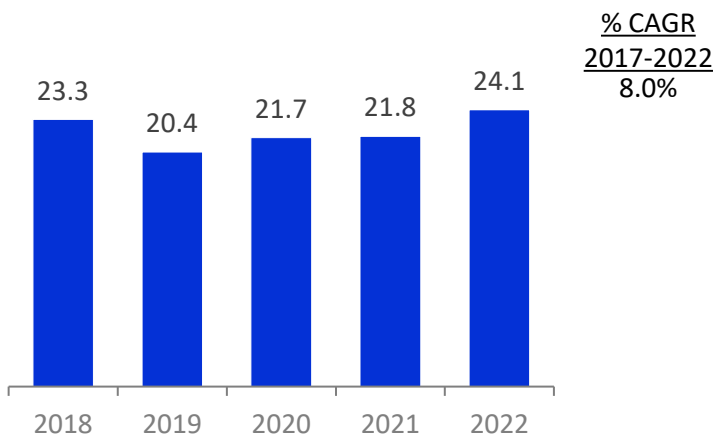
AGV & AMR ROBOTICS MARKET DRIVERS

- New factory & warehouse construction was the single most important market driver in the AGV & AMR sector
- The global switch from IC to EV technology in the automotive industry appeared to have driven up demand across the AGV & AMR sector in 2022-2023
- 'Lack of labour' has switched from robotics & automation sales pitch to a level of reality with historically low unemployment
- Access to components or supply chain disruption appeared to have returned to a new normal with very few vendors reporting unreasonable delays

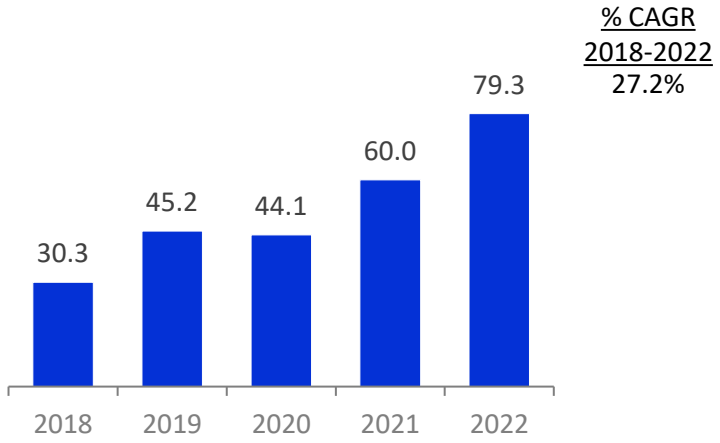
Source: STIQ Research & Analysis.

A FEW PUBLIC AGV & AMR VENDORS POSTED SPECTACULAR GROWTH IN 2022. VOLATILITY THROUGHOUT 2023 WITH SOME LEVELLING OUT/SLOWING GROWTH

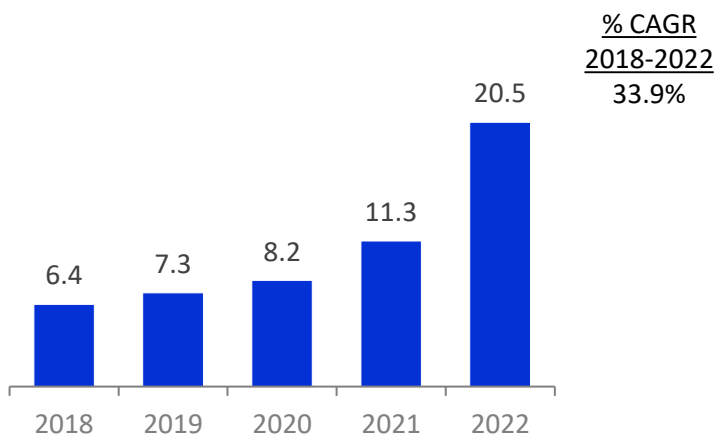
BALYO REVENUE, 2018-2022 (€m)



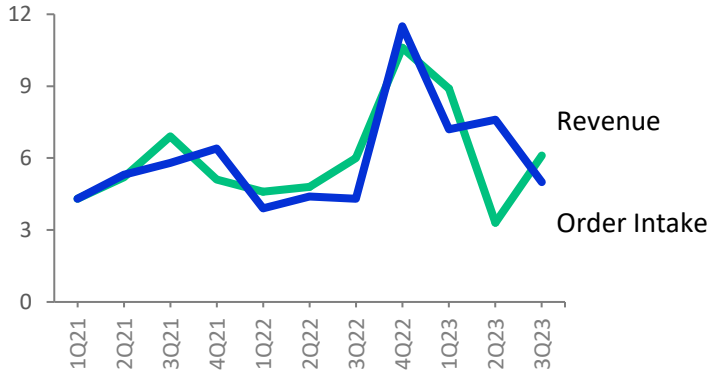
MIR REVENUE, 2018-2022 ($m) [2]



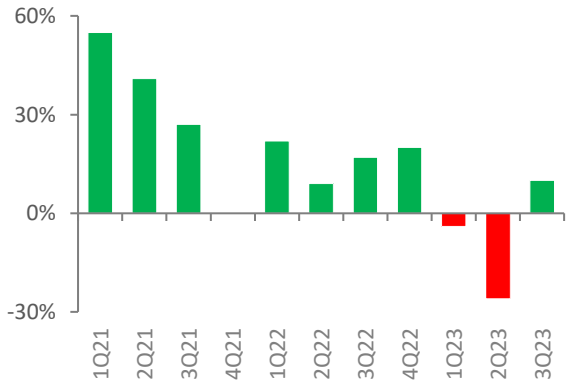
FLEXQUBE REVENUE, 2018-2022 ($m) [1]



BALYO QUARTERLY REVENUE AND ORDER INTAKE (€m)



TERADYNE MOBILE ROBOTICS (MIR + AUTOGUIDE) QUARTERLY REVENUE GROWTH (%) [2]



FLEXQUBE QUARTERLY REVENUE AND ORDER INTAKE ($m)

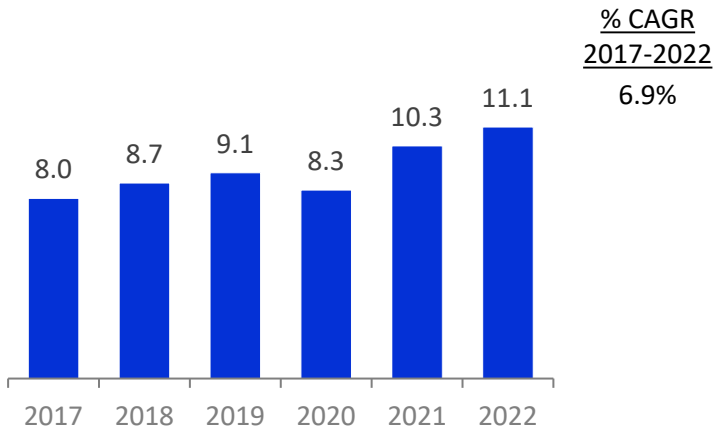
Source: Company accounts

[1] Flexqube reports in SEK. FX 10SEK=1USD

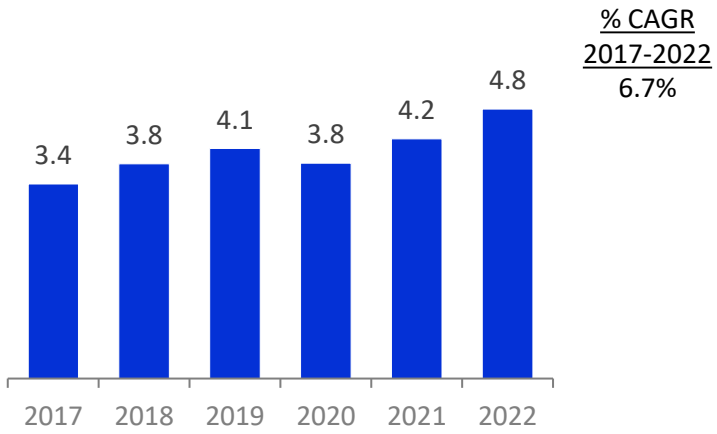
[2] Autoguide was merged into MIR from 3Q22. Teradyne forecast -10% for Robotics for 2023 (incl. UR). MIR FX 6.5 DKK - 1 USD. Teradyne does not provide break out quarterly revenue numbers for MIR. No data for 4Q21

MANUAL FORKLIFT VENDORS REMAINED STABLE. NO BREAK-OUT OF AGV & AMR REVENUE. SOME CONCERN REGARDING ORDER INTAKE IN 3Q23

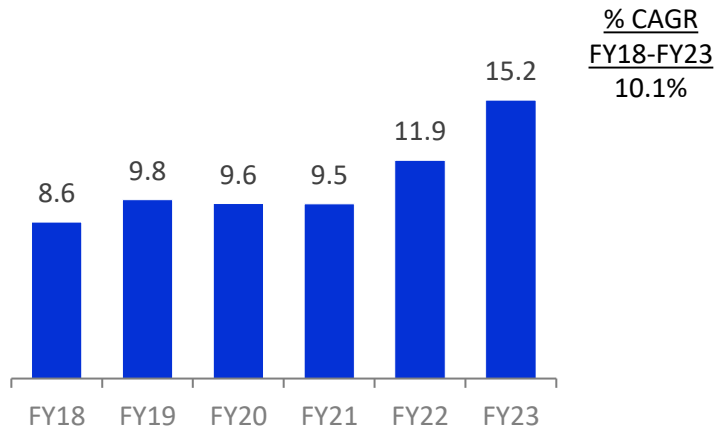
KION GROUP REVENUE, 2018-2022 (€bn)



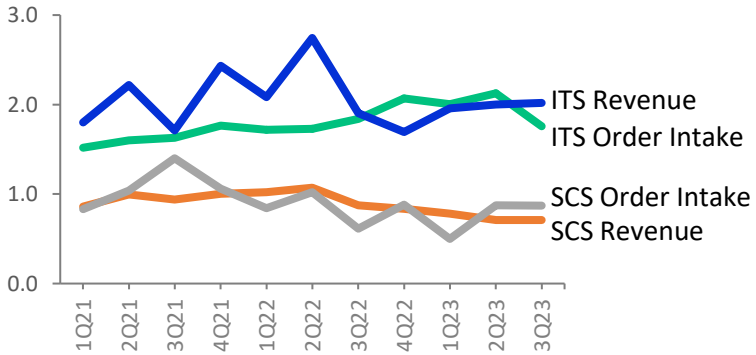
JUNGHEINRICH REVENUE, 2017-2022 (€bn)



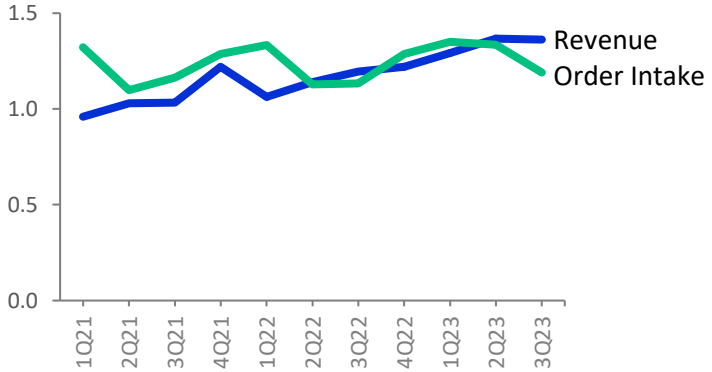
TOYOTA (TMHE) REVENUE, FY18-FY23 ($bn)



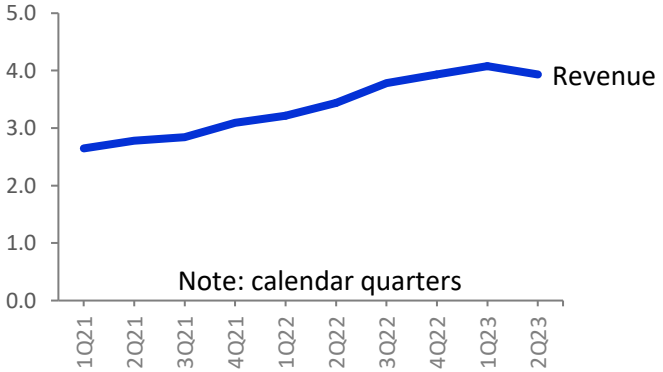
KION QUARTERLY REVENUE AND ORDER INTAKE BY DIVISION, 1Q21-3Q23, (€bn)



JUNGHEINRICH QUARTERLY REVENUE AND ORDER INTAKE, 1Q21-3Q23 (€bn)



TOYOTA (TMHE) QUARTERLY REVENUE, 1Q21-2Q23 ($bn)

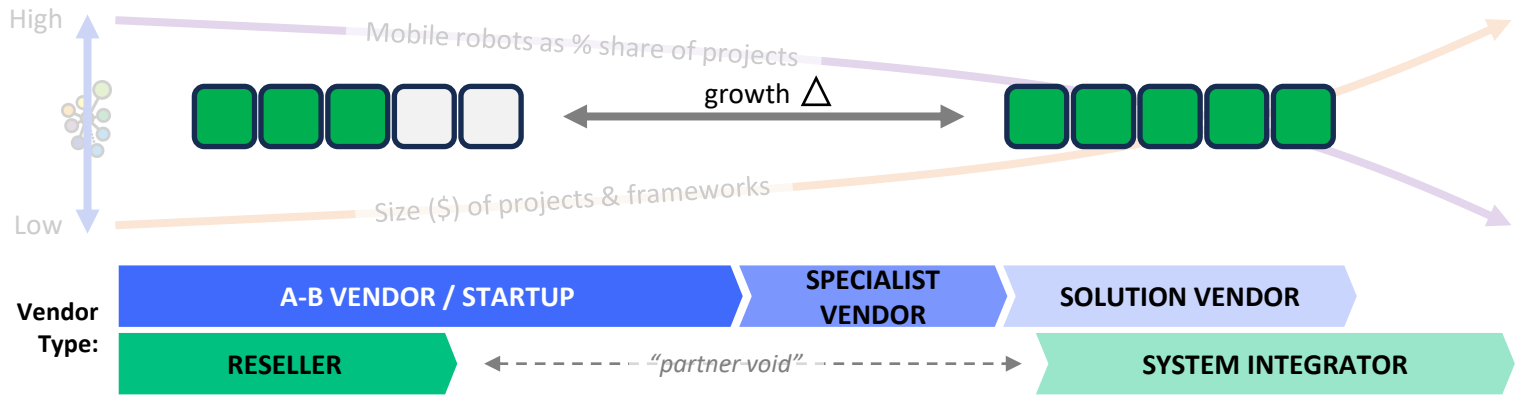


Source: Company accounts

Note: Both KION and Jungheinrich offer autonomous forklifts, but do not break out revenue. No quarterly order intake details for Toyota Material Handling Equipment division (TMHE). TMHE results boosted by Viastore acquisition in 2022. KION ITS = 'forklifts segment', SCS = Supply Chain Solutions (Dematic). FX USD 1 = JPY 150. Toyota FY end March.

GROWTH IN THE AGV & AMR SECTOR OFTEN DEPENDS ON THE TYPE OF VENDOR. STARTUPS SLIGHTLY SLOWER COMPARED TO SPECIALIST & SOLUTION VENDORS

GROWTH SENTIMENT BY TYPE OF AGV & AMR VENDORS (BASED ON INTERVIEWS)



Source: STIQ Research & Analysis

Key: High Low

GROWTH BY TYPE OF VENDOR: STARTUPS

- In STIQs experience, growth tends to vary between different types of vendors
- Startups typically provide a more positive outlook when compared to incumbents but in 2023, a level of concern appeared to have crept into the startup segment

"I see companies struggling. I see some companies really struggling." [Anonymous]

"There are also a few vendors that are having financial problems." [Anonymous]

"We see that the market is really tough now for many younger AMR vendors." [Anonymous]

- However, on the other hand, many startup vendors remained very positive and indicated good growth levels

"Last year in China, we still were in lockdown in Shanghai and so it does affect our business a lot, but still we sold more than 1,000 robots." [Anonymous]

"Revenue has grown about 60% in the first half of 2023. We just released this via Xinhua news. Internationally we see about 300%-ish growth." [SEER]

"We will grow 100% this year and we want to grow a further 100% next year." [Synaos]

SPECIALIST VENDORS

- Specialist Vendors were also very positive on growth in the short and medium term

"Our sales funnel has never been this packed. This includes the last stages of our funnel. It's complete madness and I don't know why others in the sector are playing such a dark scenario right now… for us, this year is a struggle simply because we have to invest so much money in people, in production, in entities, etc… I'm really positive about the next three years." [SAFELOG]

- In the Chinese market some vendors had established a significant beachhead in some verticals, but remained largely unknown to the rest of the world

"They are actually the leading battery sector AGV vendor and are very good at what they're doing. I think they're going to have a much easier time compared to some of the other vendors… simply because they're actually very focused in their own vertical." [SEER]

SOLUTION VENDORS

- Solution vendors often work with international clients on multi-year framework project programs
- Business was often repeat business from existing clients

"About 85% of our business is with repeat customers. So we've really built a way of working with these customers. We're doing a lot of long term programs with major consumer products companies." [E80 Group]

CONT…

JUST OVER HALF OF INTERVIEWS INDICATED A POSITIVE 2023. SOME VOLATILITY POST-PANDEMIC. DIFFERENCES COULD ALSO INDICATE ORDERS V REVENUE

- The type of customers targeted by Solution Vendors were often beyond early trial stages and bought into proven solutions

"Many of our customers are beyond beta sites and proof-of-concept installations. They understand the technology delivers the desired benefits and they are looking for us to support multiple deployments simultaneously. Customers who are just looking into their initial test site or demo are already 5 years behind their competition." [JBT Corp]

- Solution Vendors experienced huge growth during Covid with particularly high demand from the US market

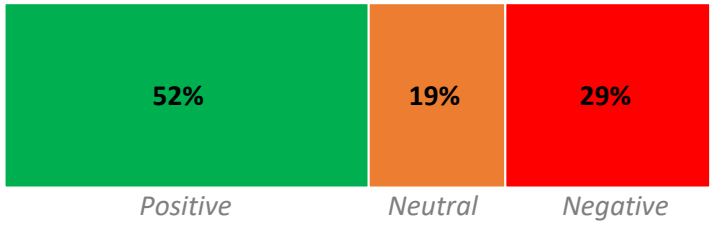
"The last 24 months have been incredible and our numbers in the US are going up very fast." [OCME]

"Revenue volume has been consistently increasing for AGVs and we still have a considerable backlog. At least a year out." [Muratec]

"We've been experiencing around 20-25% average annual growth over the last 3-4 years." [E80 Group]

"Orders continue to grow at a 20-25% rate. Growth is across multiple sectors. Traditional manufacturing applications continue with steady single digit growth while warehousing applications are growing more rapidly. The industry has a strong tailwind as companies respond to labor shortages." [JBT Corp]

AGV & AMR ROBOTICS MARKET, 2023 GROWTH SENTIMENT (%)



Source: STIQ Research & Analysis. Share of interviewees that reported positive v neutral v negative sentiment
Note: Focus on growth % in 2023 v 2022

POST-COVID, POSITIVE SIGNS

- Interviews reminded STIQ that the world has just recently fully transitioned out of Covid lockdowns and some countries remained in lockdowns until early 2023

"It's easy to forget Covid, but generally we see positive effects this year. Companies are back in action and everybody can travel. Travel restrictions were still a bit difficult in China up to April. This has released growth and the Chinese market is definitely strong. Europe has maybe seen a bit more effect of the economic situation. We've had a good year both in terms of new customers and sales." [Kollmorgen]

- The Chinese market is one of the most important AGV & AMR market but was also one of the last countries to end lockdowns which may have created a spurt in 2023

"We had a huge increase this year compared with previous years… because you know it was under Covid. We're on track to grow by 50%... so we've had a significant order intake increase in 2023." [ForwardX]

GROWTH, ORDERS VS REVENUE

- Readers should note there may also be differences between order intake and revenue. High order intake in 2023 may mean high revenue generation in 2024 rather than in 2023

"Our order intake is much higher than we thought. We have already more new orders than last year's total. And it stays… I would think that there is many more to come. So we'll end up with probably 40% higher order intake than last year." [SAFELOG]

"Order wise… for now we've already exceeded the 12 months last year. We still see very strong growth. So next year, we believe as we continue our expansion globally, that should continue the trend." [ForwardX]

SOME INTERVIEWS SUGGESTED LOWER OR NEUTRAL GROWTH IN 2023 WAS NATURAL FOLLOWING A CRAZY 2022

COMING OFF A HIGH 2022

- Furthermore, this was also contextualised as coming off a very good year in 2022 for some vendors

"Overall business for us flat in general in the year. For us that's maybe going backwards… if we don't grow then it hurts. But it will not be negative or at least that's not our prediction. But it will be a flat year, because we're coming off a high 2022. The customer projects are there and the customers need automation. But customers are holding back investments due to the uncertainties." [Anonymous]

- 2022 was a kind of crazy year for business and growth has been declining, albeit from very high numbers, but there is still growth

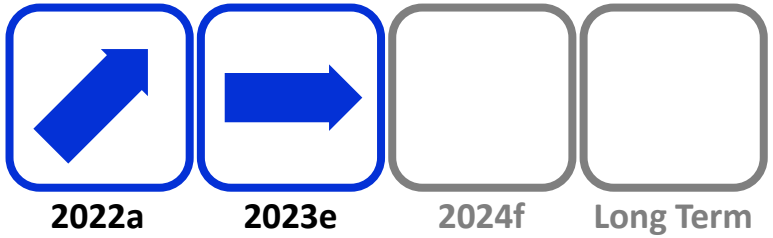
"It's definitely down a bit compared to last year which we were kind of expecting. Last year we consider as a crazy year. So no one is expecting it to be as busy as it was." [Pepperl + Fuchs]

2023, A YEAR FOR RESEARCH?

- Interviews indicated some level of hesitancy in 2023 with an increasing number of companies doing research which could potentially indicate a better 2024

"We've seen a lot of people doing research this year and chequebooks are starting to open up. I think it'll be a little better next year. But this year, certainly for most of the sector, flat or contracting." [Vecna Robotics]

AGV & AMR ROBOTICS GROWTH PROSPECTS



Source: STIQ Research & Analysis

NEUTRAL GROWTH IN 2023

- A few interviews suggested developments in 2023 had been neutral, influenced by various uncertainties

"In terms of volume, if you just count AGV's it is pretty flat this year. We're on a slight growth curve, but it's not in line with the growth that we see in all the reports of market potential and exponential growth and things like this." [Toyota MH]

"We also see a bit of decrease in the order intake pipeline. We had some challenges in the supply chain, especially with safety components. Right now it's more or less back to normal. But maybe it's also coming together with decreasing of the order intake." [Linde MH]

""This year's mobile robot sales were lower than expected, but higher than in 2022 and we still see a quite fully packed pipeline of project inquiries. However, due to some economic uncertainties such as the Ukraine conflict and energy prices, customers hesitate to push the order button. I don't see much changing in 2024." [Jungheinrich]

GROWTH FORECASTS FOR 2024 REMAINED LARGELY OPTIMISTIC ACROSS VENDOR TYPES

AGV & AMR Robotics, Nov 2023
Published by WWW.STIQ.LTD
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AN OPTIMISTIC VIEW ON 2024

- Interviews suggested a broadly positive view on prospects for 2024, especially in the US market

"We've seen a boom in opportunities in North America in the last 24 months… and the trend continues. It's more of a reality now that there's a need to modernize production and connecting that to a warehouse or a distribution warehouse connected to a production site… there's a lot of runway ahead of us yet. We primarily work in high volume consumer products." [E80 Group]

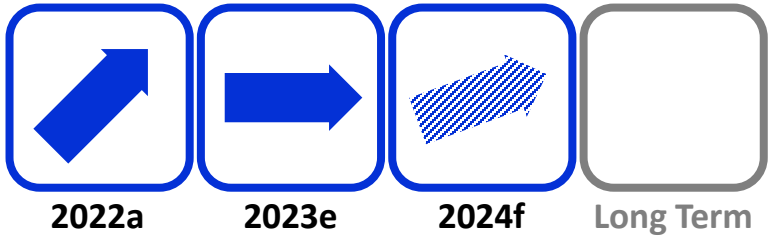
"As a company we see more than 50-60% growth. But in AMR we see c.20-30% growth." [Addverb]

"Our partnership with TGW offers us completely new opportunities. Together, we conclude contracts that we would not have been able to obtain on our own." [SAFELOG]

"One of the vendors in the Spanish mobile robots association expects 85% growth next year." [Moving Robots]

"We anticipate strong growth for 2024." [BlueBotics]

AGV & AMR ROBOTICS GROWTH PROSPECTS



Source: STIQ Research & Analysis

STARTUPS LARGELY POSITIVE

- Startups were also positive, however, it is also in their DNA to have a positive view on future prospects and they are also able to post many 10's of % growth, often from a relatively small base

"We're still expecting to grow quite a bit… not necessarily like the exponential numbers we have had for the last few years. But we're expecting ourselves to grow quite a bit because we believe we're positioned a little bit differently. We make controllers, key components, things like that which is very unique in the market. We don't really find any competition here in China. We're not expecting our robot sales to grow as much as our components for sure." [SEER]

"If I look at my enquiries, it's going up every week." [Karter]

- Some software vendors viewed the potential for 2024 as less challenging, partly because of their business model and lag to scaling with navigation

"We are quite optimistic about 2024 because we onboarded some customers in 2023 who are now ready to scale to at least 2X or 3X the number of robots. While sales cycles have typically been long, scaling after the initial deployments tends to happen quite quickly from our experience. This directly contributes to our revenue. I'm confident in further doubling or ideally tripling. There's still a little uncertainty on the overall growth of the industry and how many projects get realized. But overall we are very optimistic about the coming years." [NODE Robotics]

HOWEVER, OTHERS INDICATED SOME CONCERNS AND SUGGESTED A SLOWING 2024, BUT WITH A POSITIVE LONGER-TERM MARKET

SLOWING MARKET FOLLOWING 2022, 2023?

- As the market has been very strong up to now, there were some concerns this may dissipate

"We have some doubts about the near future. Because the market was very, very strong up to now. That is the point. So to keep always at a high level… I mean we really hope, but there are many factors…. some points in Europe and next year will be an election year in the US. There are many things that can influence the economy." [OCME]

- Some interviews forecast that order intake could slow down in 2024

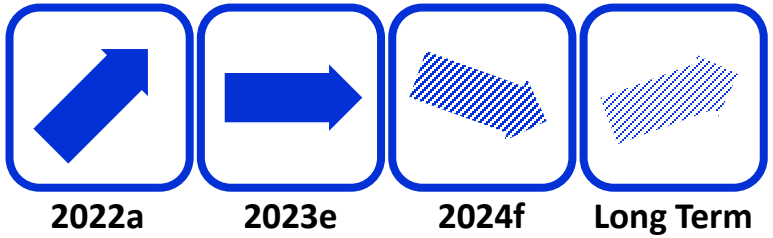
"I think from an order intake point of view, in 2024 we'll see a little bit of a slowdown." [E80 Group]

INCREASINGLY SCRUPULOUS WITH ROI'S

- There appeared to be an acceptance that the very heightened level of business experienced during 2021 and 2022 was inevitably going to lead to a return to normal

"2024 revenue wise will be a very good year… in that +20% range. In terms of growth we're on forecast. What we have noticed is that not everything is sunny. Some companies are pulling back a little bit. They're being much more scrupulous with their investments right now. We're seeing… it's not a pullback, but a slowdown. A couple of companies have said they're going to stay put this year. Other companies with multiple sites are continuing but maybe doing 3 sites instead of 5." [E80 Group]

AGV & AMR ROBOTICS GROWTH PROSPECTS



Source: STIQ Research & Analysis

"What I've seen is that customers are more scrupulous in ROI... I think there's a lot more pressure on companies across the board. For automation the business case really has to be there. People are hoarding more cash and waiting and they're clearly not spending at the levels they were. The urgency is really down." [Vecna Robotics]

- On the other hand, some vendors also indicated customers were weighing ROI less in decisions whilst putting more emphasis on business aims and/or targets

"ROI, historically, has been around 2-3 years, but that's changed now. Customers' expectations drive a lot of investments, not just necessarily the personnel or the cost for them to lease a machine, but considerations like what they are trying to do with their company, how much are they trying to grow, over what time period, and what will it take to sustain that growth. ROI is still important, but it almost feels like it has not been a driving factor lately. It is definitely a consideration, but not the final decision maker." [Muratec]

LONGER TERM EXPECTATIONS POSITIVE

- The AGV & AMR Robotics sector has experienced steady growth and was expected to continue in a similar way
- Immediate growth expectations depended a bit on who was interviewed and their business model

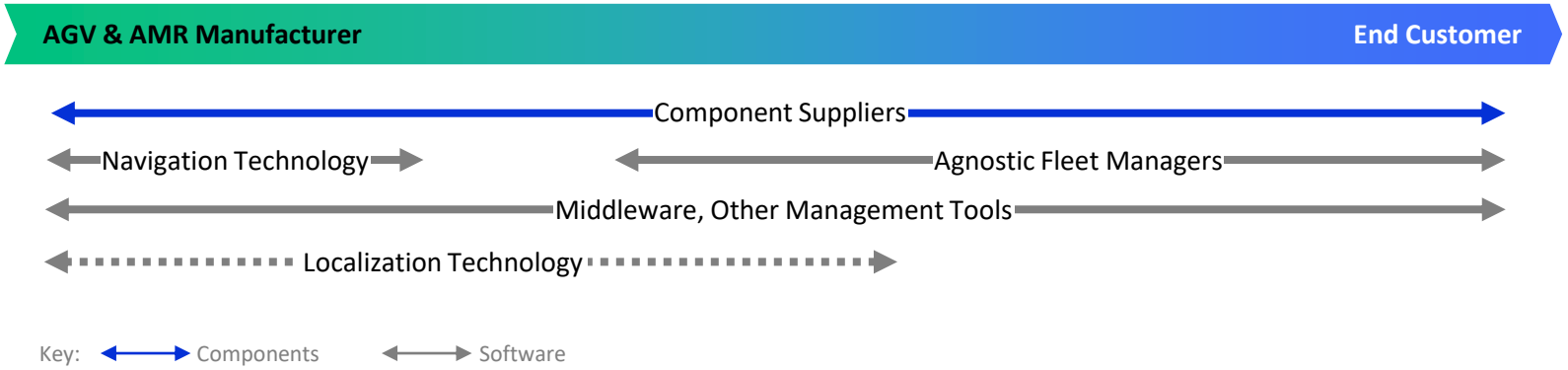
"And as far as the AGV market goes, we're always expecting that to keep increasing over the next several years… I would say it's in the 10…20%... that type of range." [Pepperl + Fuchs]

"I'm actually quite bullish on the AGV & AMR market. It might not sound like it, but I'm actually quite bullish. In the short term… there's going to be some shake up in vendors and there's been some consolidation recently." [Christensen Strategy Group]

"With our robots I still see the potential for growth from where we are. The market is still there. I don't think that the market itself is growing at the same rate as we can grow. We can grow a bit faster than the market. I think we will get a bit more order intake in a controlled growth manner. Because we also need to build up our organization at the same time... everybody needs commissioning people, everybody needs these experts, which is not so easy to find." [Linde MH]

COMPONENT AND SOFTWARE SUPPLIERS SHARED AN OVERALL POSITIVE SENTIMENT FOR THE AGV & AMR ROBOTICS SECTOR

COMPONENT AND SOFTWARE SUPPLIER TARGET MARKET/S



Source: STIQ Research & Analysis

COMPONENT SUPPLIER GROWTH

- Various component and software suppliers may sell to different sections of the AGV & AMR market which could also impact growth prospects

"We are still growing very fast at 30% plus per year. This year also, if we just deliver our current orders, we will be reaching the record again in the AGV & AMR segment." [Mobotic]

"There is a high demand for new AMR topologies and components as well as requests to reduce design-in phase. A lot of machine builders are entering and building their own or buying vehicles. The number of players is still growing." [Bosch Rexroth]

- Interviews also confirmed that AMRs are growing faster than AGV type navigation vehicles – but from a smaller base

"Sector growth is closer to 10-20% I would say… c.10% for line based navigation and c.20% for the Lidar." [Pepperl + Fuchs]

SOFTWARE SUPPLIERS

- There has been a surge in new software startups in the AGV & AMR sector in the last 5 years and these tended to have very ambitious goals

"We have quite ambitious growth goals. Obviously, the 4th quarter isn't finished yet, but at least you can see where it is going. In the summer we were a little more optimistic about this year. We reduced it a bit, but it still will be quite a successful year for us." [NODE Robotics]

- Incumbent vendors may view growth from a longer-term perspective, and from a different size of operations

"We are getting more and more customers, it's more the macroeconomic situation that is accelerating or slowing down our growth rather than the competition." [BlueBotics]

SOME MARKET GROWTH LAG

- Some suppliers can also experience a lag to prevailing market conditions

"The productization phase can be anywhere between 6-24 months. For smaller customers, the productization phase is typically under 6 months. But for larger companies, it takes longer due to internal processes such as design, procurement, manufacturing, and support." [RGo Robotics]

- Complex software solutions can also take time to implement making growth difficult during projects

"I think fast growth is difficult because… we offer a very specific solution with a high level of customization per project. With one of our big customer in foods, we can grow in this area and implement our software all over Europe and the rest of the world." [Movizon]

INFLATION COMBINED WITH SUPPLY CHAIN DISRUPTION PUSHED UP PRICES BY 10-30% ACROSS THE SECTOR. IMPROVED LEAD TIMES

PRICES HAVE INCREASED C. 10-30%

- Interviews suggested prices for AGV & AMR Robots have increased on average by about 10-30%, following input cost increases

"Everybody's prices across the board are probably 30% higher than they used to be or something like that." [Vecna Robotics]

"I would say that everybody increased the prices by at least 20% in the last two years." [Mobotic]

"We did see a price increase for sure, because every time you have a supply restraint, you will see some effect of that." [K. Hartwall]

"Pricing is affected by various factors, like increases in our supply chain costs to remain able to deliver. While fluctuations are prevalent, our software prices have remained on the same level." [Bosch Rexroth]

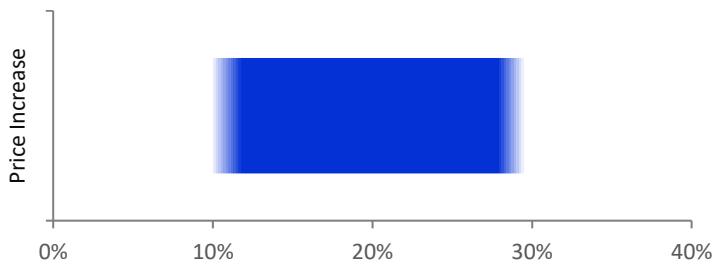
"In general, prices are a little higher. Lead times have come down a bunch. Price increases have been around 15%, not more." [JBT Corp]

- Component price increases appeared to be a major cause, but general inflation had also pushed up other costs, such as staffing, etc.

"Component prices are still elevated, and I think as long as vendors are paying that price, those prices will stay elevated. I can't ever see the prices going back down. Lead times are getting a little better." [Muratec]

"In general, we've seen the price of electronics increasing." [E80 Group]

AGV & AMR PRICE INCREASES (AVERAGE)



Source: STIQ Ltd research & analysis

- Interviews also suggested improvements in product technology had also pushed up costs

"There is an increase in the price. But this is not only because of component price increases. Our technology has also improved and safety requirement are also increasing with new certification requirements. The increase is only 5-10%." [Addverb]

SOME VENDORS PROTECTED MARKET

- A few vendors were aware of their position in the market and had decided to take a potential margin hit

"We increased our prices over last year based on the higher costs. But we have also a decreasing of end customer prices. We want to keep the product attractive for our network. I think a general effect is that our purchasing prices are not increasing further, so we have quite stable prices which we can now provide to the end users with a more or less stable lead time. Lead times are quite attractive in general." [Linde MH]

COMPONENT PRICES NOT COMING DOWN

- It was unlikely that component prices would decline, at least in the short to medium term

"I don't really see prices going down" [Pepperl + Fuchs]

"Prices are not coming down, but the ease of getting the component is back to normal delivery times." [Mobotic]

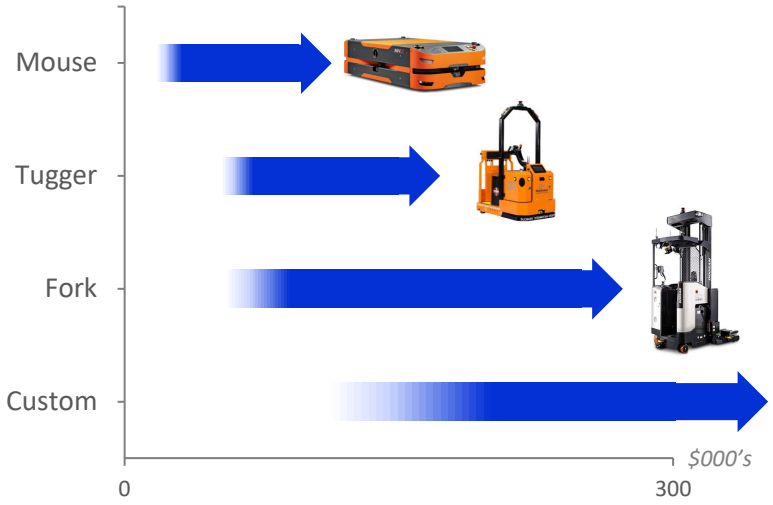
FURTHER INCREASES ALSO POSSIBLE

- Interviews suggested new legislation may add new safety or other requirement layers to AGVs which could drive up prices further

"The EU Machinery Directive was first published back in 2006 and has now recently been updated in 2023, focussing on new technologies and how they can ensure human safety. HMS Networks are at the core of this dynamic shift in the directive's direction, as this regulation will be fully active and enforceable in 2027, helping our customers understand this update and advising them how to remotely stop AGVs and AMRs, and how safety events should be supervised." [HMS Networks]

PRICING OF AN AGV & AMR VEHICLE OFTEN INFLUENCED BY A DEGREE OF CUSTOMISATION WITH MANY DIFFERENT VARIABLES AND CONFIGURATIONS

TYPICAL PRICE RANGES BY FORM FACTOR ($000's) – VEHICLE ONLY (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

PRICE OF A SINGLE VEHICLE (SIMPLIFIED)

- Readers should note any pricing indication was often considered a vastly oversimplified overview of the AGV & AMR Robotics sector due to the many different variables
- However, although in general prices for a single vehicle tended to follow the pricing in the chart above, they could still vary dramatically

- For example, a smaller deployment with <5 vehicles, may not require a fleet manager and there may also be no need to integrate with business systems such as ERP or WMS, each of these would have a cost impact
- Customers often also had a choice of batteries (Fe, Li, etc.), charging modes (wireless, contact), navigation technology, motor configurations, payloads, chassis modifications, etc.

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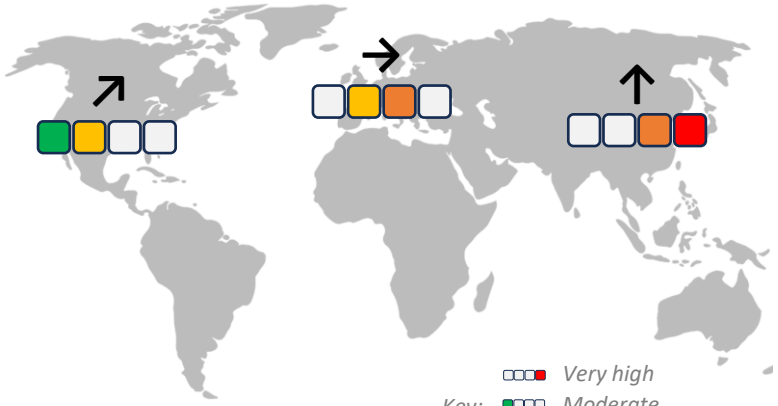
THE CHINESE MARKET HAD SLOWED DOWN AND WAS PLAGUED BY HYPER COMPETITION AMONG THE MANY 100's OF DOMESTIC VENDORS

COMPETITIVE INTENSITY INDICATOR



Source: STIQ Research & Analysis

HYPER COMPETITIVE ENVIRONMENT

- Interviews with Chinese vendors have nearly always hinted at a very competitive domestic market, however, this appeared to have reached a new level in 2023

"In China, competition is crazy on price and services… even I have seen some larger companies selling projects at a loss." [Standard Robots]

"The competition here in China is completely at a different level." [SEER]

- End users appeared to buy mainly on price, potentially also due to a lack of differentiation between vendors

"The market situation in China for AGVs is quite competitive. End users are very price sensitive and this has driven down prices. In the beginning it was good because every company had to increase production efficiencies to drive price improvements. But in the long run it's unhealthy because everyone feeds the market with lower and lower prices." [Hangcha]

- Covid may have been a contributing factor, but a fast growing number of vendors in the space also influenced lower price expectations

"Because everybody in this industry had a tough period during Covid and there are some competitors that try their best to do every project. So there are very low quotes and maybe they are adding some other extra services so the price competition in China it's quite huge." [Standard Robots]

COMMODITISATION OF MOBILE ROBOTS

- It should be noted intense price competition appeared to be centred on Kiva type robots (datametric, e-Commerce robots, covered in STIQs G2P Solutions reports)

"The Kiva segment is super competitive. You can get a robot for <$10k easily in the Chinese domestic market if you have a project of 200 robots. It is less competitive in the SLAM space, but still there's quite a bit of pressure. At the end of the day some of these Kiva type vendors are also trying to position themselves in the industrial sector and SLAM is where they're going as well. That's almost the same story for all the bigger vendors. But some of these companies have realized that industrial automation is not something that they are going to invest in." [SEER]

- However, other robot segments including SLAM vehicles were also affected

"We have adjusted our product strategy quite a bit in reaction to the request from our integration partners, whom are feeling increasing pressure from their end and requested our support to stay competitive.. In terms of the driver behind that, I think the main reason is the lack of growth in the market and a lot of companies have invested a lot and they have to make a living… if the market is not growing as fast as people were expecting and yet a lot is invested… and even we see more companies entering the market. It's natural to get more fierce competition." [SEER]

COMPETITION, A DRIVER OF INNOVATION

- To grow their businesses, quite a few vendors had resorted to offering OEM services

"Some Chinese AGV & AMR suppliers also start the OEM business." [Hangcha]

- Furthermore, the huge proliferation of vendors in China had also made it difficult to market product differences
- STIQs conversations with multiple Chinese vendors highlighted a stronger focus on innovation to develop solutions 'to be known for' as a kind of branding exercise

"If we're just copying other's product there's no point of difference. What we want is to advertise this one. It's completely original, completely designed by us." [Anonymous]

INTENSE COMPETITION IN CHINA + LIMITED GROWTH = MULTIPLE VENDORS TARGETED OVERSEAS MARKETS IN 2023 AND 2024

OVERSEAS EVEN MORE ATTRACTIVE

- A hyper competitive domestic market combined with the re-opening of travel appeared to have boosted Chinese vendors' determination to target overseas markets

"Actually we started the overseas market in 2018 and we had some projects in the US. Then Covid arrived so we have focused more in the Pacific areas. Right now, we have a mature sales system in Japan and also some key projects executed in South East Asia." [Standard Robots]

"We made a strategy to really boost our overseas business, especially in the US and Europe." [Hangcha]

- Some vendors had the benefit of group companies in the various target territories

"I can tell you that the Hangcha group… in the US we also sell hand tools, like power tools. So we already have very good solid relationships with like the big box retailers in the US. We have some good customers… the direct customer already for AGV in the US." [Hangcha]

US, EUROPE AND JAPAN KEY MARKETS

- Interviews suggested the US was the primary target market alongside SE Asia/APAC markets including Japan

"US, Europe and Japan… these three will be the priorities for us. And you know in the US, they have the volume. We're talking about some very large projects because they have the producers and right now the economics is running back in the US." [Hangcha]

"2023 for us is to do international investigation. We do lots of trade shows in SE Asia and the US. Next year we'll do some business execution. We are very confident for next year's development." [Standard Robots]

"Well, we're also in the middle of expanding so I would say we're seeing things go up… primarily in the US, Australia and Asia." [ForwardX]

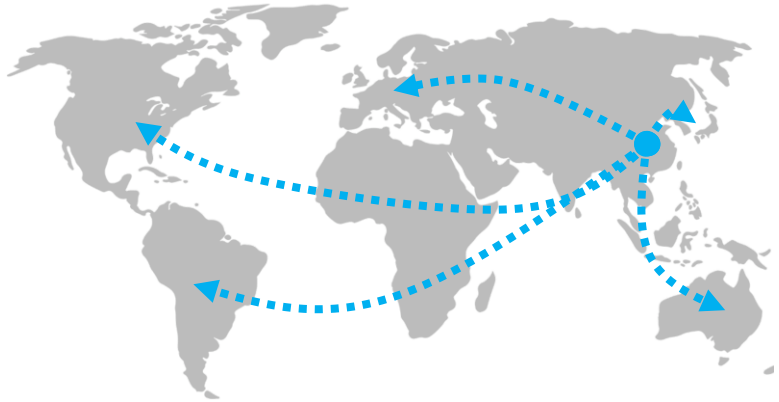
- Interviews suggested a belief that North American and European markets would grow faster, possibly even faster than China

"For the future I would expect North America and Europe to grow a lot faster than the rest of the other areas, even including China. The economy is not really doing as well as expected. It's not a decrease, but the growth of the budgets from our end users, from our integration partners is not as good as people were expecting." [SEER]

- The business culture in the US and Europe was perceived as more focused on performance when compared to the domestic Chinese market's apparent vigorous demands
- These markets were also perceived as less competitive

"Doing businesses is very demanding in China… you do mostly networking and business negotiating things. But in foreign markets, we see less struggle in such kind of work. People mainly talk about the technical things, if you can meet requirements, the project will go very smoothly compared to the Chinese market… and there are also less competitors." [Standard Robots]

CHINESE VENDORS EXPANDING GLOBALLY



Source: STIQ Research & Analysis

- Despite attractive markets in Europe and North America for Chinese suppliers, there were also important differences in the level of urgency to automate when compared to Asian markets

"The difference between European or American customers to Chinese or APAC customers is that they don't have the same urgency. They do not build many more new factories and bring the robots to their factories. But in the new factories in China, Thailand, Vietnam, they're urged to do so." [Anonymous]

ESTABLISHING OVERSEAS OFFICES WAS TOP OF THE AGENDA FOR MANY CHINESE VENDORS. FOR SOME, POTENTIALLY A SURVIVAL STRATEGY

INTERNATIONAL OFFICES, STAFFING

- Overseas markets remained very attractive, but also demanded a different approach to distribution, installation, maintenance and servicing

"We sell other products in China. For the overseas market we try to reduce the number of products we're selling because it's easier for us to handle. We have limited choices for the customers overseas to make the implementation and service easier for us." [Anonymous]

"We attended a US exhibition this year and we also met many end customers during that show. The feedback was quite good and people were interested in projects and in our products. But there are still some delays on communications and concerns we need to focus on like technical services and support. Right now we are planning to visit the US to do some research for subsidiary offices location and also to review existing and potential projects." [Anonymous]

- Appointing distributors appeared to be the favoured route into the European market

"In the US, Japan, and Korea we have our own sales and deployment teams. But for Europe and Australia we will only develop distributors. The reason is… like Germany, France, Italy, Spain... it's way too complicated. We prefer to go with our partners and distributors, they're in the markets and know the language and have the set up… the difficulty with Europe as far as building our own team… there're differences between countries within Europe in terms of culture and language." [ForwardX]

- Chinese vendors expanding into other countries were known to aggressively target experienced staff

"This week I received a call from an HR manager from one of the Chinese vendors. They wanted to hire me. They are very aggressive in the market and offer you a real generous salary package." [Anonymous]

OVERSEAS MARKETS SAFETY REQUIREMENTS

- But exporting also means higher requirements on safety functionality and certification processes

"We are starting to work with AGV manufacturers in China. Because that market is not growing as expected and they are looking to export… and for exporting they need more safety, they need more performance. Other type of requirements." [Synapticon]

"We still highlight European markets. We see there is demand. But we think it will be challenging, compared to other countries, especially certification." [Standard Robots]

POTENTIAL POLITICAL HEADWINDS?

- Chinese robots were perceived as competitive, but there were also headwinds in some sectors and elections in the US in 2024 could also bring additional hurdles

"Chinese vendors have very competitive products and the pricing is very different from ours. They are potentially a threat for our product for sure. But due to the political risks, none of the customers that we are working with are choosing the Chinese AMR, so I don't really see them as a competitor right now. But yeah, we do benchmark them, of course." [Anonymous]

A MATTER OF SURVIVAL FOR SOME

- Competition combined with lower growth appeared to have pushed some vendors close to the limit
- This could potentially have a 'dead cat bounce' effect on the market with even lower prices

"There's a couple of Chinese players who are really fighting for their survival… which is also increasing competition in the short term." [Anonymous]

- Interviews suggested consolidation may occur in the wider AGV & AMR Robotics sector, in particular in the Chinese market

"Regarding the global market of AGVs/AMRs, most of the Chinese manufacturers say they will soon have an IPO, but recently the automation market situation in China is cooling things down a little. Therefore, this might create a consolidation in the AGV market, especially with Chinese manufacturers as they need to expand into the international market to diversify their market mix." [Anonymous]

THE US MARKET, GENERALLY ACCEPTED TO BE 10 YEARS BEHIND EUROPE IN AUTOMATION, APPEARED TO BE FIRING ON ALL AUTOMATION CYLINDERS

AGV & AMR Robotics, Nov 2023
Published by WWW.STIQ.LTD
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US COMPETITIVE INTENSITY INCREASING

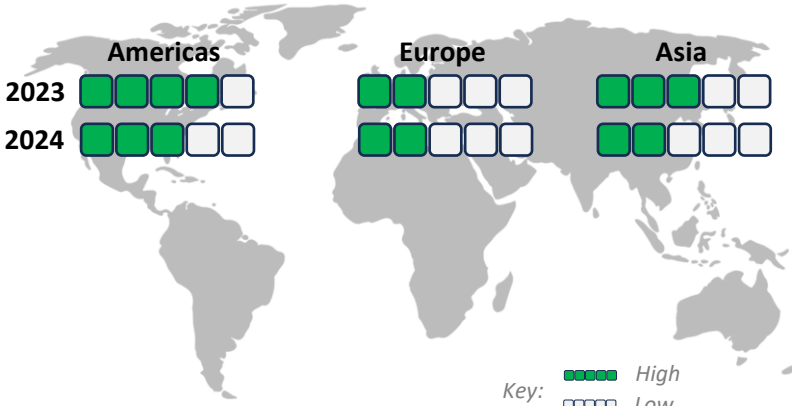
- Interviews suggested the US market had remained relatively insulated from macroeconomic and geopolitical headwinds experienced in Europe and Asia
- There also appeared to be significant tailwinds in the North American market, partially driven by Covid impacts and near record unemployment rates

"If you would have asked me three years ago, I would have said that the US and the European market are very similar. I would have told you we see the same trends, the same kind of drivers. But that has changed… maybe not radically. But one of the drivers for automating in the US is this lack of labour. I would say that the US has been quite slow to automate but now… you can see the very low numbers for unemployment. There's a kind of push for automation right now. It's partly driven by those companies that are more visionary." [Kollmorgen]

"The US is generally thought to be 10-15 years behind Europe in automating. European companies were simply forced to start automating earlier due to lack of low-cost labor. This is now happening in the US, but they can now take hyper jumps across a few development steps that Europe went through and go directly to the good stuff." [K. Hartwall]

"There's a couple of companies, especially in F&B logistics, that we're going to do our first projects with in 2024. Our partner TGW has a strong footprint in the US and together we had the first two projects." [SAFELOG]

AGV & AMR ROBOTICS GROWTH INDICATOR



Source: STIQ Research & Analysis

- The 'lack of labour' arguments was used by robotics companies to market their products, but often there are underlying causes for a lack of labour, such as simply not paying enough
- However, in the US this had now reached a point where it was difficult to find people, and automation ROI looked increasingly attractive

"In comparison with the US… the Japanese market is relatively slow in terms of the AGV & AMR demand. But I think it's coming because of the labour shortage issue which is getting worse and worse every year. The US market is having the difficulties of finding labour." [Lexxpluss]

US, AN INCREASINGLY ATTRACTIVE MARKET

- It was not only Chinese vendors who viewed the US market favourably; many European vendors also planned to expand operations or to set up new offices

"We are planning to open an assembly line end of next year. In 2025 we want to deliver the first mobile robot made in the USA." [SAFELOG]

"We are expanding into North America currently driven by client demand." [idealworks]

- The US made up a core part of the global AGV & AMR market

"If you club together the US, China and Europe that makes up almost 80-90% of the entire AGV & AMR market. The rest of the world is hardly 10-20%." [Addverb]

2024 ELECTIONS, POTENTIAL CURVEBALLS?

- Whilst US demand remained strong, there was also significant potential for disruption with the 2024 election approaching, potentially pitching curveballs to the economy

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THE SWITCH TO ELECTRIC VEHICLES IN THE AUTOMOTIVE INDUSTRY WAS A KEY GROWTH DRIVER ALSO PULLING IN OTHER SECTORS, SUCH AS BATTERIES

AUTOMOTIVE, THE KEY GROWTH DRIVER

- The ongoing switch from combustion to electric vehicles continued to drive demand in the wider automotive industry

"Everybody is building battery plants and changing plants for electric cars." [JBT Corp]

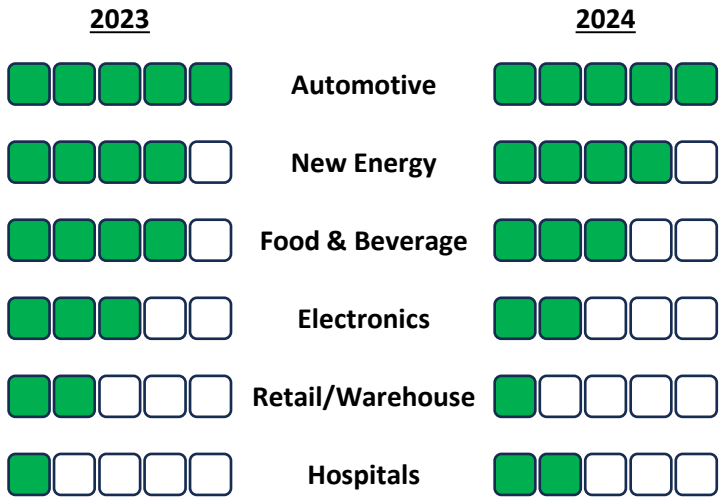
"We see major demand coming from the EV sector. Traditional auto is also growing, but a lot of new orders are coming from building up new EV plants. Companies like BYD are actually building a new plot every month. And Chery, produced >1m vehicles in 2022… they are all still in a very strong growth phase." [ForwardX]

"New Energy includes Batteries, EV's and Solar… and this is an area where we see a lot of growth, especially in India." [Addverb]

- Traditionally, automotive has been a very cyclical customer base for AGV & AMR Robotics vendors and there may be cause for concern in a few years

"The automotive segment has been one of the more cyclical markets with peaks and valleys depending on the overall economic cycle. With the transformational shift of electrification, the current up cycle is significantly higher and will likely be longer than we have seen in the past. Engine/transmission plants are now being reconfigured to motor/battery plants. The automotive industry is responding very quickly to customers, but it is a huge shift for them and not just a typical model changeover." [JBT Corp]

GROWTH BY SECTOR (SENTIMENT)



Source: STIQ Research & Analysis.
Sentiment from interviews

- However, customers in the automotive sector were often much larger than any other industry verticals

"Automotive vs warehouse is about 50/50. However, for warehouses the per order size is much smaller than the automotive. Because automotive customers usually order 50-100 vehicles per site. But we have many more sites in warehouses. We are also in the manufacturing sector… we see strong growth domestically this year especially with car manufacturers. We also received very good growth from the US, Japan, Australia, Europe… we are still in the expansion stage so there is growth in most places." [ForwardX]

"About 25% of our customers are within automotive and 15% within electronics. The rest is very mixed across general manufacturing with internal logistics." [MIR]

- Navigation software vendors had also received inquiries from the automotive sector

"Currently we have one request from an automotive OEM. I think it is more that they like to see how they can optimize their processes and once they have everything, then take it to the supplier and go back to their business as usual." [NODE Robotics]

NEW ENERGY, SOLAR, BATTERIES

- New Energy, including batteries and renewable energy sources such as solar, was one of the industries currently expanding heavily requiring mobile robots

"The renewable energy industry has grown very fast. That was one of the government supported industries in China a few years ago and many of them are trying to expand as quick as possible and that's why they build factories and they're demanding mobile robots." [Anonymous]

"We still have some focus on some key industries semiconductor, automotive, manufacturing and also for new energy and lithium battery. This year we made huge progress in solar and battery. One of our clients in battery manufacturing, they have contributed $15m of projects over 2 years. So there's a huge increase for the demands in this industry. There was a huge increase in the EV industry." [Standard Robots]

F&B REMAINED A SIGNIFICANT SOURCE OF AGV & AMR SECTOR GROWTH, ESPECIALLY IN THE US. INCREASING INTEREST FROM GENERAL LOGISTICS AND 3PLs

AGV & AMR Robotics, Nov 2023
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FOOD & BEVERAGE STABLE GROWTH

- F&B was also an increasingly attractive market with growing demand

"A lot of our customers are in the automotive sector. Because in this sector they have a lot of AGVs. But we also do projects with non-automotive… for example in F&B e-commerce. These are projects which we are quoting at the moment, but there is no decision yet… we realized our sales cycle is really long. We talk about 8-16 months and the VDA5050 is only 2.5-3 years old. So the market is only 3 years old." [MHP]

- Many of the Solution Vendors have tended to focus on the F&B sector with continued growth

"There's been a number of new production facilities that have come online, as well as some intralogistics centers that have come online in the last three years… some companies are also taking their logistics operations in-house again, moving away from 3PLs." [E80 Group]

- F&B and automotive appeared to drive most growth in North America and Europe

"F&B is more or less stable, also pet food is going up." [OCME]

EXAMPLE OF AGVs & AMRs IN THE FOOD & BEVERAGE AND CPG/ FMCG INDUSTRY

Image Source: OCME (YouTube)

"Our main customer sectors are F&B and automotive." [Muratec]

"We're not expecting much from retail & e-commerce in the next year. But in manufacturing and F&B we still expect more from the mid-sized companies." [Addverb]

WIDER LOGISTICS AND 3PL ALSO ACTIVE

- Unstructured sectors such as 3PL's were also increasingly visiting trade shows inquiring about automation

"We're expanding sales to logistics and manufacturing companies, particularly in the automotive sector. The shift from IC to electric vehicles is driving interest… many companies are looking for increased investment, prioritizing efficiency and safety over immediate ROI... they don't really talk about ROI. Perhaps they are confident of a post-implementation ROI recovery?" [Lexxpluss]

"In automotive manufacturing you have very well-defined processes which are ready to be automated. In logistics industry you have a different starting point. However, 3PLs are also eager to automate their processes. But, as they usually don't have very well-defined processes and a lot of mixed traffic in their warehouses they need another feature set. Focus in 3PL is on flexibility, autonomy and ROI of around 2 years to fit with their customer contracts situation." [Jungheinrich]

"We have had RFQs for every big company you can imagine that is doing any kind of logistics in the past 2 years. In automotive, aviation, electronics." [Movizon]

"Key AGV & AMR customers are all the classic ones that you can think of… automotive, electronics and those type of sectors… pharmaceutical can use them as well." [Robot Center]

HOSPITALS REMAINED A GROWTH OPPORTUNITY WITH OFTEN CYCLICAL PURCHASING FOR BROWNFIELD LOCATIONS. CHALLENGING BUT INTERESTING DEVELOPMENTS

HOSPITALS, LARGE CYCLICAL OPPORTUNITIES

- Hospitals represented a relatively large, generally untapped opportunity for AGV & AMR Robotics
- However, opportunities could also be cyclical, often hindering further development of suitable solutions

"We've been active in the hospital market for over 2 decades and during that time, it's been cyclical with a lower quantity of projects, but each can be quite large. Hospitals often require more upfront planning to make sure the system has the appropriate space to operate. And in competing for funding, cost saving AGVs can lose out to revenue generating diagnostic equipment. Since many hospitals are not private businesses, we may see an uptick in government legislation creating incentives to automate." [JBT Corp]

- And, not all hospitals were set up for automation, especially mobile robots in older brownfield buildings

"I was in a hospital in Liverpool a couple of days ago and it's a newish hospital, but they haven't thought about automation and where everything is located from a workflow perspective. I was looking at it and I was just saying, look it's not going to work efficiently. On the flip side of that, I have been contacted by another city who's building a new hospital and they now talk to us about the width of corridors and where we should put everything for an automated system to work efficiently. I mean, it's definitely coming." [Robot Center]

INCREASINGLY PLANNING FOR AUTOMATION

- Interviews hinted that automation was increasingly a consideration in new hospital construction

"In Europe, in most of the places, they do not do new hospitals without planning for AGVs… in Spain, Italy, Denmark, Germany, Switzerland. It's really coming and we also see that there are existing hospitals where they are putting the vehicles. This is a bit more difficult because if you did not design the environment for it, you have some challenges, but it's coming. I don't expect this to be like e-commerce." [BlueBotics]

- However, it appeared there were early initiatives to include automation at an earlier stage - STIQ received a few inquiries from global architecture firms in 2023

BUSINESS MODELS ALSO PLAYING A PART

- Management and potential outsourcing arrangements could also play part in any decisions to automate or not
- Some hospitals were apparently managed similarly to a 3PL operation with relatively short contracts that did not appear to encourage automation

"Some of the larger hospitals tend to be managed by an outsourcing firm and they're just looking to save money. Because its mainly about people, they see the robot as an upsell to sell more people. But then they need to spend more money to get an ROI. So instead of spending 30k on a person, you're now going to spend 250k and achieve a return in 3-5 years. But that doesn't work for them because their contracts are only 3 years." [Robot Center]

EXAMPLE OF AGVs & AMRs IN HOSPITALS

Image Source: Kollmorgen NDC (YouTube)

THE WAREHOUSE CASE PICKING APPLICATION VIEWED AS LOW HANGING FRUIT IN THE AGV & AMR ROBOTICS SECTOR. MENTIONED BY MANY DIFFERENT VENDORS

EXAMPLE OF CASE PICKING

Image Source: Mecalux

AUTOMATING CASE PICKING, A HOLY GRAIL?

- Multiple vendors interviewed for this report indicated they viewed the case picking process as a huge opportunity for their products

"We have a tugging application for case picking. An operator picks cases into a cage in the aisle. The load is kept at the end of the aisle and our tugging bot collects the cage and delivers it to a staging area. We have done this with one of the biggest grocers in the US." [Addverb]

"And then additionally what we have as a strength is that we have a case picking supporting use case, where the operator follows the vehicle. This is a specific use case where we are also capable of doing it in freezing environments." [Movu Robotics]

"One of our customers are looking for a specific use case for order picking. They would have 3-4 roll containers on a forklift and order pick to these. They would drive in the aisles, the driver would step off and pick directly into those roll containers… in the future you can solve that with an AGV that can automatically drive to the outbound area which creates a lot of interesting ROI calculations because suddenly you can also go into a setup where the train comes into the aisles and then you don't have the drivers following the train. This way one person can stay in the aisles and just pick orders." [K. Hartwall]

"Industry-wise we cover warehouse automation. We have the assisted picking solution. However, we not only do eaches, we also do case picking and we also have an autonomous forklift for in- and outbound." [ForwardX]

3PLs, THE NEXT GROWTH DIMENSION?

- Factories and production environments were often aware of automation and how to improve efficiencies
- One of the next big growth industries was partially viewed as increased penetration among 3PLs where case picking was often a major activity

"I really do think that once you get into the 3PL's, the logistics companies with a solid application… we cannot address that segment with AGV technology. I think AMR technology is absolutely crucial to open up that market. Then you will see that the other killer application that we are waiting for and that we certainly are working on is order picking. We can do A-B transport. We can do VNA. We can do a number of let's say storage solutions, but the one actually in the biggest part is order or case picking." [Toyota MH]

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BROWNFIELD ACCOUNTED FOR THE MAJORITY OF PROJECTS, BUT GREENFIELD PROJECTS LARGER. ADVANTAGES AND DISADVANTAGES WITH BOTH

GREENFIELD V BROWNFIELD

- The split of greenfield/brownfield depended a bit on which vendor was asked, but in general brownfield sites appeared to account for a majority of projects

"Most of our customers are building new factories." [Anonymous]

"Some 60-70% of what we do is in brownfield sites." [E80 Group]

"It is about a 60%-40% split, with 60% brownfield. The reason is companies are increasingly looking at how they can expand in their existing buildings. There you don't have to worry about any delays in building the facility and then automating it. That portion has remained the same. I think the biggest kicker now is it's just driven by that lack of labor and trying to maximize what they currently have." [Muratec]

"In the US, we are more in the brownfield and worldwide we can go even to the greenfield." [OCME]

ADVANTAGES / DISADVANTAGES

- Interviews suggested both green/brown had their respective drawbacks and advantages

"We work in both greenfield and brownfield. Greenfield is somewhat easier, and you can design around the other automation. Fitting within a brownfield can be very challenging. Customers often have to invest a considerable amount in getting the facility ready for automation, retaining their personnel, working amongst automation, and so on." [Muratec]

SECTOR BROWNFIELD V GREENFIELD PROJECTS

Source: STIQ Research & Analysis

- Existing workflows can be a challenge, but vendors can also evidence their suggested impact near immediately

"In some ways it's easier to do a brownfield site than a Greenfield site because you have an operating factory… you have to be very good at not shutting things down obviously. Going into a brownfield has the advantage of you are in a plant that's actually operating and you don't need to wait for various construction delays." [E80 Group]

"In an existing workflow it's a challenge to integrate robots." [Moontech]

THE GREENFIELD

- Greenfield opportunities can be significantly larger

"If you think of a continuum of complexity of applications, on the high end you have a greenfield site that will be fully automated and it's a $50-100m integrator project. On the other end of the spectrum, there is an existing brownfield facility with a little bit of lean operational budget perhaps to be used to try something new." [Christensen Strategy Group]

- Interviews suggested greenfield opportunities getting larger whilst brownfield sites becoming smaller

"We do see a trend that greenfield sites are becoming bigger and brownfields a bit smaller." [ForwardX]

- Greenfield projects can often drag out due to the many different stakeholders

"Oftentimes, greenfield sites drag on and it's 1-2 years after that you finally see all of the flows coming together and you end up going back and reworking certain things because you don't start to see the full efficiency of a system like this until it's really being pushed." [E80 Group]

THE BROWNFIELD

- Brownfield opportunities can often be limited in scope due to existing infrastructure, potential floor issues, etc.

"It's very rare that we turn up to a site that has so much space that you can deploy hundreds of robots." [Robot Center]

- Customers have to consider which changes are required for AGV & AMR vehicles

"Most of our work is in brownfield. It's very hard for us to fit into a regular facility that is doing no rack changes at all. Normally customers have to consider changes. Their facilities are optimized for manual trucks. When it comes down to it, the physics for an AGV is exactly the same in terms of lifting height and stability of the vehicle. But we have safety bumpers front and rear, so we're never going to be able to go as tight as a manual truck does." [JBT Corp]

THE EARLY POST-COVID ERA APPEARED TO HAVE CHANGED CUSTOMER BEHAVIOURS AND IMPACTED MARKET DYNAMICS. POSSIBLE BIFURCATION OF PROJECT SIZES

CHANGED MARKET DYNAMICS

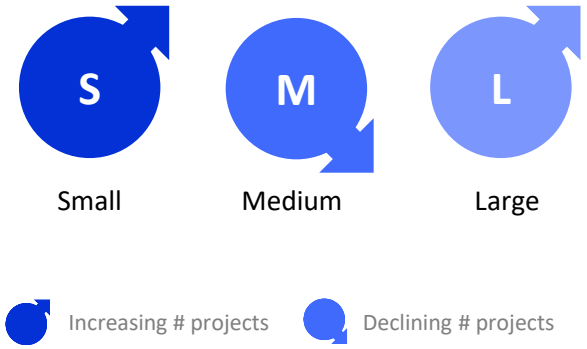
- Interviews suggested behaviours and market dynamics may have changed post-Covid, but that the medium to long term impact of such changes was not clear
- There were three short term trends:
  - Customers: Larger and smaller project sizes (bifurcation)
  - Customers: Quicker projects, with short or no notice (longer term planning increasingly difficult)
  - Vendors: Increasingly selective approach to projects (increased risk, profit margin management)
- Some of these dynamics could also be 'natural' consequences of the market maturing or companies moving into a new phase

BIFURCATION OF PROJECT SIZES

- STIQs impression from interviews was a bifurcating market where large projects were increasingly larger and small to medium sized projects perhaps smaller

"Mobile robots are more present than ever and our project sizes are growing significantly. It's probably more than double than it used to be… Let's say our average project was €XX three years ago… it's probably closer to €YY now. It's a lot bigger projects with a lot more units in a single project. And we get project sizes up to €ZZm. The way we do business has changed because of this and we adjusted a bit. Sales cycles are longer." [Anonymous]

BIFURCATION OF PROJECT SIZES



Source: STIQ Research & Analysis

- This market behaviour also appeared to apply to some of the software vendors

"In the last 10 years we moved away from having few big customers. We had 3-4 quite big ones and perhaps 5-6-7 average ones. This year we are missing the average ones. We have a few big and a lot of smaller ones." [BlueBotics]

- However, in a maturing market such as the AGV & AMR Robotics sector, larger projects could also be a natural development

"There's more big projects than there used to be and perhaps people are more selective on who they're going to trust on a big project. We have a track record on big projects and not a lot of companies have this. For example, one RFQ asked us to prove that we have experience of 100+ units project. We have more than a handful of projects with 100+ vehicles." [SAFELOG]

- Supply chain disruption and growing concern re lack of labour could also have forced customers to automate and, in some cases, go big immediately

"Right now we are already discussing investment for 2025 with some customers, which is like unbelievable. Because of this supply chain disruption with longer lead times. But it's only recently improved so for people that are discussing big investments, they are still thinking it could be first in 2025 for example." [OCME]

PROJECT SIZE VARIES BY CONTEXT

- Note that project sizes remained relevant to the type of AGV & AMR vendor (see also page 11)
- For example, forklift projects tend to be smaller in volume terms when compared to mouse vehicle projects

"5-10 forklift vehicles is a medium project. Below that is a small project. Everything above 15 is a large project. We're currently doing a project with about 60 vehicles and another project ongoing with 18 vehicles, but these larger projects are not that frequent and the core volume that we do sell is coming through small to medium sized projects. I'm very proud to say that every single project we did last year was profitable." [Toyota MH]

UNCERTAINTY AND VOLATILITY HAD TURNED FORECASTING INTO ‘A FINGER IN THE AIR’ APPROACH FOR MANY. “IT’S HARD TO SAY WHAT NORMAL IS THESE DAYS”

MORE DIFFICULT TO FORECAST DEMAND

- Interviews suggested volatility in the Covid and post-Covid era had made forecasting more of an art than science and that what was normal pre-Covid possibly no longer applied, at least in the short term

“It's hard to say what normal is these days.” [JBT Corp]

“As you know, forecasting has become a little difficult in recent years.” [Addverb]

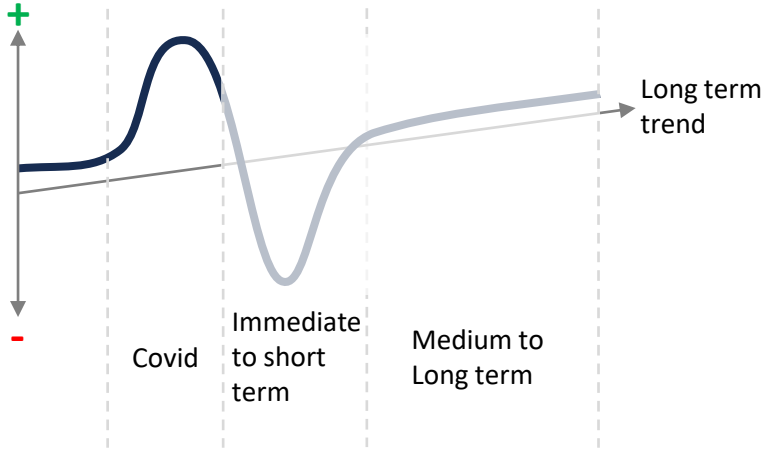
“A big part of our budget is based on the forecasts of our customers. You can imagine what happened in 2020. Then in 2021 it should be better, but still it was trouble. Then we say 2022 this time we can really rely on customer forecasts and of course we did not consider Ukraine and then supply chain issues…” [BlueBotics]

- Reading signals from customers whether or not a project was going ahead or if it was postponed, or even terminated, had become even harder

“Market dynamics may have changed a bit and it feels like projects can come up a bit faster and be executed a bit faster. It's a bit more difficult to have a very long projects tunnel. This is just my general feeling.” [Kollmorgen]

“Some of our customers also talked about that they kind of had projects in their pockets and then all of a sudden these got rescheduled for 2024. I think there's a lot of uncertainty also on the timing and when will project actually be provisioned and pushed forward.” [NODE Robotics]

VOLATILITY, SHORT TO LONG TERM IMPACT



Source: STIQ Research & Analysis

CUSTOMERS POSTPONING DECISIONS

- STIQs reports throughout 2023 highlighted projects being delayed across material handling sectors
- The AGV & AMR Robotics sector was not isolated from this trend
- A level of uncertainty appeared to have crept into decision making

“There's just a lot of uncertainty. On one hand, the US market is doing better than other parts of the world. But you can also tell from talking with clients that there's a lot of socioeconomic fear. In Jan 2023 nearly 100% of economists talked up a recession… and we're still going strong. But buyers are still wary of that.” [Vecna Robotics]

“Throughout 2023, projects have been pushed further out. They have not been lost and closed, but the decision time takes much longer.” [MIR]

- However, interviews also suggested some of the delays in the AGV & AMR sector may have been impacted by other dynamics, such as fleet management decisions

“This year a lot of projects were postponed, partly due to the fleet management software issue, but partly also we see it as a lot of investments delays. A lot of projects got postponed. But we are maybe not as gloomy as the macroeconomic situation for next year where we do see that there is, let's say, visibility in the project that's now coming through… In general, we do see business picking up.” [K. Hartwall]

“Some clients are delaying projects… some of these delays are due to the overall economic situation. On a positive side, the clients that we started working with this year all went operational right away.” [idealworks]

RISK MANAGEMENT WAS AN INCREASINGLY IMPORTANT TOOL FOR VENDORS. A SELECTIVE APPROACH TO PROJECTS APPEARED TO HAVE ENSUED

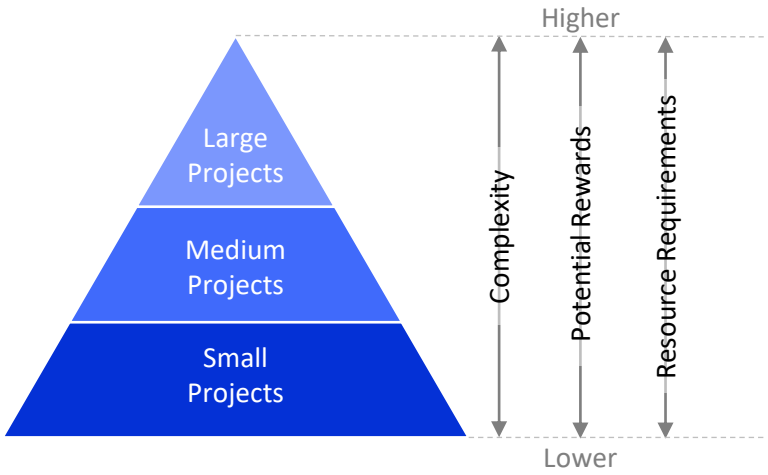
RISK MANAGEMENT APPROACH TO PROJECTS

- Project risk management was not a new trend on its own and has been practiced my many AGV & AMR vendors
- However, an increasingly volatile market with changing dynamics could require more careful management of larger and potentially riskier projects
- Typically this would manifest itself by focusing on many smaller projects with a few medium, and even fewer large, projects

"For AGVs, I will try to remain the same next year. I may do some larger-scale projects, but we've had discussions and will be even more critical next year. I don't want to put the company in the position where we overbook or oversell ourselves and then fail to execute or have to announce unnecessary delays. Because of the amount of competition we have, reputation is critical. So you want to do everything you can to protect that reputation in the market." [Muratec]

"We try to keep our growth internally at no more than a 10-15% increase. That's mainly because of production capabilities. But we've chosen to avoid the 1-2 unit systems that don't have a lot of growth potential. Again, we have a very niche market that we go after, the fully customized units with 5-20 units with customers where this is their first attempt at automation, but there is a lot of growth potential. They're using pallet systems in one facility to prove the concept, then grow within that facility and then cross over into multiple states and cities." [Muratec]

PROJECT RISK MANAGEMENT (SIMPLIFIED)



Source: STIQ Research & Analysis

- Some newer vendors were increasingly aware of the need to risk manage and be more selective about which projects to bid for instead of bidding for everything on the market

"The domestic market in China has seen maybe some shortage of projects. This may be some impact from Covid-19. There were some postponed projects this year. 1Q23 and 2Q23 were slow but there is lots of demand. We haven't quoted on all projects like we usually do. We choose the projects to pick up the profitable ones. So that's the strategy change. So this year we have sacrificed many projects and we put more effort in the overseas market." [Anonymous]

- However, picking profitable projects may be easier said than done

SMALLER PROJECTS OFTEN BUSINESS DRIVER

- Some vendors viewed smaller projects as the bread and butter for their business

"Homeruns are great, but it's the singles that feed us. The singles keep the lights on. I'm not shying away from that because these are relatively turnkey projects." [Koerber Supply Chain]

CONCERNS RE FRAMEWORK CONTRACTS

- Enterprise customers may sign long term contracts which also bring their own set of potential liabilities especially when input prices are volatile

"If you're not doing well now, then it's tough. Some of these contracts we have, we got them a long time ago. And if you didn't have things built into those contracts for escalation and things, sometimes you know with all the delays you're paying a lot more for those parts than you had expected a long time ago." [JBT Corp]

"The demand for autonomous intralogistics is growing. The challenges are on the supply side. Today all vendors need to mitigate increased political and supply chain risks by either keeping stock of key components or accepting production time increase from 8 to 20 weeks. In framework agreements with fixed price lists such supply chain volatility can affects margins of enterprise deals." [Versabox]

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MULTIPLE INHIBITORS FOR FASTER GROWTH IN THE AGV & AMR ROBOTICS SECTOR. MARKET GROWTH REMAINED AT UP TO 10% ANNUALLY (ON AVERAGE)

TOP INHIBITORS PREVENTING FASTER GROWTH IN THE AGV & AMR ROBOTICS SECTOR

Inhibitor	Description	Impact
Inexperienced customers	• The majority of customers were not aware of changes required to their businesses, processes and workflows and software integration	↓
Infrastructure changes	• Brownfield environments often require changes to physical infrastructure which can be as easy as moving a shelf to fit a charging station, but also require customers move pallet racks by 20cm to abide by safety standards	↘
Customisation	• Nearly every project requires a level of vehicle customisation • This is particularly prevalent in forklifts • Some vendors have developed catalogues where buyers can configure vehicles	↘
Fragmented market	• Difficult for end customers to know which vendor to go for as there was no leading vendor • Extends buying process as more vendors to be curated	↘
Lack of ownership	• Once a customer has bought and deployed and AGV & AMR solution, it is rare they take psychological ownership - including the expertise to change the running of robots to make their business more effective	↘
Lack of System Integrator layer	• A continued lack of system integrators for AGV & AMR Robots has meant vendors have dealt directly with end customers, impacting their ability to scale internationally • Appointing resellers with lack of AGV & AMR knowledge also often required significant training to allow these companies to sell larger solutions	↘
Marketing	• Some marketing have indicated AMRs are easier to implement but AGVs + AMRs are relatively similar in terms of deployment requirements • This may have driven up the number of unqualified incoming inquiries • Some marketing has also trained customers to focus on features and technologies rather than efficiencies (see also inexperienced buyers)	→

Source: STIQ Research & Analysis.

CAVEAT FOR INHIBITORS

- Note this report **excludes e-commerce applications**, such as Goods to Person pick solutions – covered in STIQs G2P Solutions reports (download here)
- Such e-commerce applications were more similar to AGV & AMR Solution Vendors where the end customer may care less about which robots are being deployed with a focus on actual throughput

AGV & AMR ROBOTICS MARKET INHIBITORS

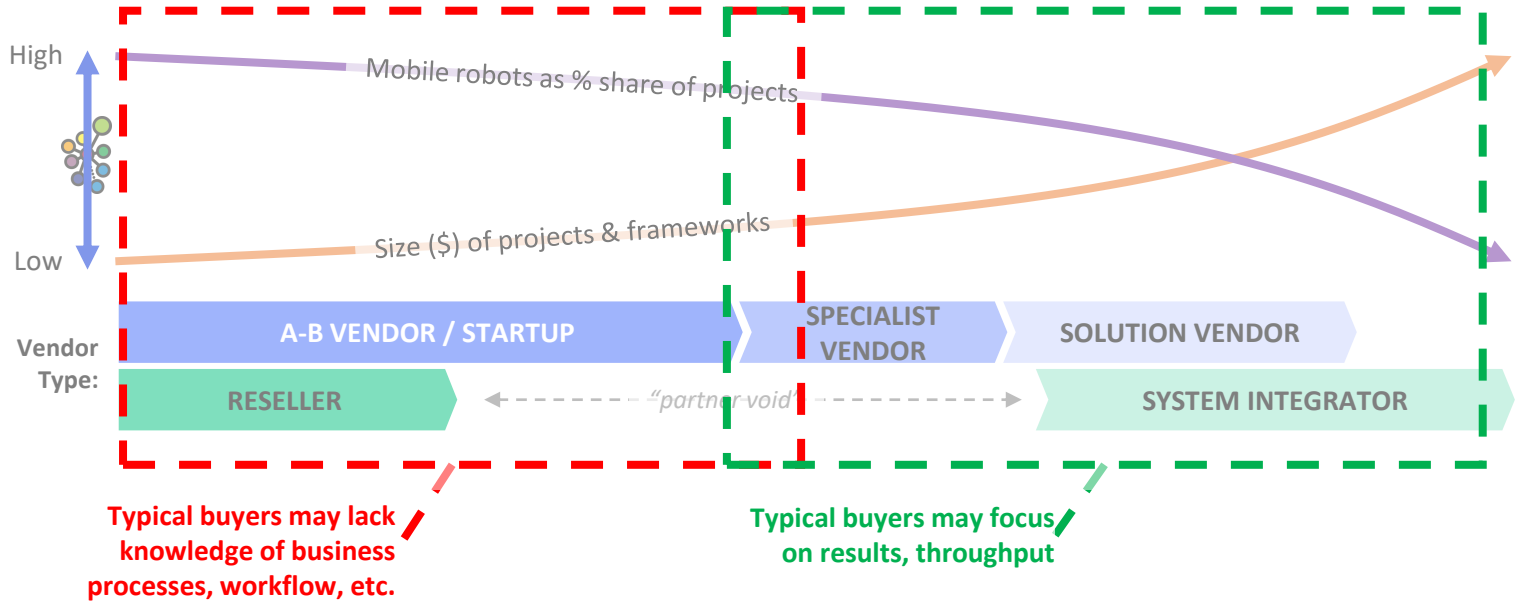
- Interviews have suggested there are multiple inhibitors for **faster** growth in the AGV & AMR Robotics sector
- Some of these inhibitors are more relevant for certain types of AGV & AMR vendors
- Inhibitors include a lack of end customers experience and knowledge of their own workflow and processes combined with required infrastructure changes
- Significant customisation requirements was widely viewed as an industry-wide inhibitor in the market
- Fragmentation slowed down the buying process and also confused potential buyers

"It's definitely slowed down the buying process because there's a lot more products around than just 5 years ago. You've now got 50-60 different AMR vendors to pick from." [Robot Center]

- A lack of large and international system integrators was also hampering growth prospects

MAJORITY OF INHIBITORS PRIMARILY APPLICABLE TO BROWNFIELD SITES AND YOUNGER VENDORS OFTEN SERVING POINT-TO-POINT SOLUTIONS

TYPES OF AGV & AMR ROBOTICS VENDORS AND DIFFERENCES (SIMPLIFIED OVERVIEW)



TYPE OF PROJECTS SERVED (GENERIC)

CAPACITY/ POINT TO POINT

- Customers mainly buy smaller deployments to replace single processes, such as point to point transfer

RESULT/ OUTCOME

- Customers buy an outcome and/or throughput, not a system of AGVs & AMRs which they need to manage themselves
- Throughput may be guaranteed

Source: STIQ Research & Analysis

LACK OF KNOWLEDGE INHIBITOR

- STIQ have found that one of the primary inhibitors for AGV & AMR Robotics growth is a lack of knowledge among end customers
- This was particularly pronounced among customers just starting out with their first project and who are typically served directly by startup vendors or resellers
- In larger projects, customers typically buy a solution and may not often care about the equipment used to achieve the solution aim
- This also presented a significant moat for newer vendors to gain a presence in the market

"Customers buying from a robot vendor are paying for capacity, not results. That puts the product at odds with what the customer is trying to do. So, why do proposed productivity targets not get realized? It's all of the above. There are lots of variables outside the vendor's control, which is true. But if you have technical and usability problems, which are within their control, that makes them have lower adoption overall. So there's less confidence from the customer side." [Christensen Strategy Group]

- To overcome this moat, a few startup vendors specialised directly from day one whilst others have developed specialist solutions or product catalogues

"We're automating a process and not just a vehicle. We auto unload and load trucks using this big flat low slow AMR that can carry 8-10 pallet positions at a time… 3 of our robots will fill a 53-foot trailer." [Slip Robotics]

SOLUTION VENDORS OFTEN SELL PERFORMANCE AND THROUGHPUT WHEREAS A-B VENDORS MAY BE SELLING CAPACITY AND POINT-TO-POINT SYSTEMS

SOLUTION VENDORS, PRE-SALES PROCESSES

- Solution vendors often spend a significant proportion of projects in the pre-sales phase, analysing customer data and really understanding the details of business processes, forecasts and required outcomes

"We've always spent a ton of time in the pre-sales phase. That's the key to making a successful project… at customer sites scoping out projects and digging into the details. That's why it takes sometimes 1-1.5 years to come up with a finished product because you're going through so many iterations." [E80 Group]

- This also allows many of these vendors to often produce a guaranteed outcome

"What I was reading in your article last year which was very interesting to me was the fact that you really have to dig into the details and know the customer's business. Perhaps you had discovered things that they didn't know about their business and that's what allows you to get to that point of guarantee." [E80 Group]

- Incumbents have also developed processes to understand and interpret customer requirements

"In the early discovery meetings, we're often able to identify if it's a true need for AGVs or if it will be more of a headache than good for the customer. We try to be very open and transparent, and we don't string them along. If we're a fit, we'll let them know we're a fit and our potential solution. But if we don't have an offering for them or what they're asking for doesn't make a lot of sense, then we notify them as early as possible." [Muratec]

THE A-B VENDOR/ POINT-TO-POINT

- Interviews suggested large parts of the market may be focused on selling point-to-point solutions which may not create customer value for continued traction

"I think that the AMR vendors are mainly doing point solutions. This doesn't create enough customer value to get real growth traction. There's a common account expansion strategy of pilots-to-fleet-to-enterprise, where you always get a customer who kicks the tires first and they're not really sure and it's still sort of leading edge technology, depending on the customer that you're talking to. So they're not really sure, but that's not the biggest problem. The biggest problem is after you get the pilot in and they're trying it out, is that it's just not connected to the overall enterprise in such a way that it scales organically." [Christensen Strategy Group]

- Importantly, vendors should try to get involved in more of the value-added processes

"You've got to get yourself inserted into more of a flow, and that means you've got to get past the islands of automation. You've got to be integrated into more than one system such that you are a cog in a bigger machine. And then you can enjoy the benefits of some of those growth trajectories. But if you're on the outside, if you're peripheral, if you're an island, it's just not gonna work." [Christensen Strategy Group]

- But, when customers first dip their toes in robotics, they often do so on sub-production lines or in non-critical processes

"Customers prefer not to implement completely new systems on their main production line. Instead, they test them on secondary or logistics lines. We aim to initiate the low-risk aspect of the process, starting with a POC - a baby-step approach." [Lexxpluss]

- But, scaling from a pilot/trial to a fleet can be a problem if customers cannot clearly evaluate and/or use the pilot

"You're not going to go from pilot to fleet if they can't use the pilot." [Christensen Strategy Group]

MAJORITY OF INCOMING LEADS FROM CUSTOMERS WITH LITTLE TO NO AGV & AMR KNOWLEDGE. NOT A 1:1 REPLACEMENT OF MANUAL VEHICLES

AGV & AMR Robotics, Nov 2023
Published by WWW.STIQ.LTD
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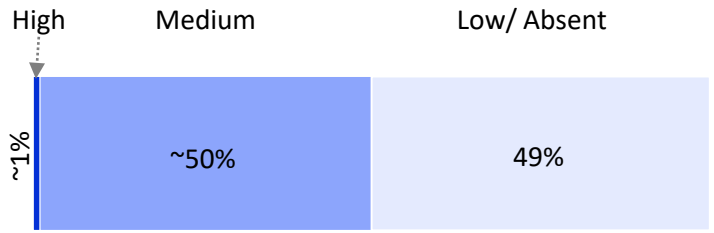
LEVEL OF PROJECT COMPLEXITY APPRECIATION BY POTENTIAL AGV & AMR CUSTOMERS



Source: STIQ Research & Analysis, interviews

LACK OF AGV & AMR KNOWLEDGE

- interviews suggested it is very rare to come across people with intimate knowledge of how to implement mobile robots in their workflows and processes

"For example, from 100 potential customers. One customer is fully prepared. They know exactly what they want. They have seen it and have expectations. Then you have 49 which have no idea, but they like the robots. Then you have another 50 which are a little bit in between those two." [Karter]

"It's very rare that you come across someone who really understands what you have to do to get mobile robots working properly in processes, especially with all the H&S and CE markings and so on." [Robot Center]

OFTEN SIGNIFICANT TRAINING REQUIRED

- Sales teams often have to execute resource intensive training with potential customers

"And many of the leads for this kind of AGV & AMR item are not familiar with automation. That's why also our sales team takes time for kind of user training or need to start explaining about how automation should be or something like that." [Okamura]

"I still think we're in the 20-80 rule. What I mean by that is that you have 20% which know about robots and investing in robots and changing stuff in robots. But, there's another 80% of industry which hasn't even thought about mobile robots… not on their radar. And we're still in an education phase for this 80%." [Robot Center]

- Education can be arduous, but with a good process, there can be positive results

"The most important thing when you have leads is education. You have to educate the customer about what an AGV is, how to use it, what you have to prepare to use it successfully. The question is also who will be the integrator and who will be in charge to make it work? If it is Christmas Day and your 24/7 production stops because of an AGV - who do you call and who will come to solve it?" [BlueBotics]

"Many potential customers want to have a demo. Bring a machine to my place - Yes, but what do you want to see? Because in a demo the robot can move A-B, but this is often not what customers want. They want to see it integrated in their processes and software, working together with people. But this is very time and resource consuming to set up." [Karter]

NOT A 1:1 REPLACEMENT

Source: STIQ Ltd Research & Analysis
Images: source, source

AGVs & AMRs, NOT A 1:1 REPLACEMENT

- Some buyers that are new to automation or AGV & AMR Robotics frequently consider robots as a potentially 1:1 replacement for manually operated vehicles

"If there's no automation, many customers may start with a 'replace the driver' approach." [Toyota MH]

- However, in reality a mobile robot project is likely to include a level of change

"Certainly there's a process reengineering part and that this is going to work a little differently, it's not just a 1:1 replacement of your manual forklift and a lot of people still can't wrap their heads around that." [Vecna Robotics]

"The last thing you want to do is emulate what you're doing manually. That's usually the biggest mistake you could make." [E80 Group]

NEW CUSTOMERS OFTEN INVOLVE EXTENDED SALES LEAD TIMES AND A RELATIVELY HIGH POTENTIAL FOR FRICTION

EXTENSIVE SALES TIMELINES

- Plenty of customers were trying out smaller deployments to test and seek out where to find efficiencies, how to operate robots, etc.

"The large global accounts are often the ones who have the highest readiness for AMRs and also the highest potential. But with those customers, as well as with any other customer, they often start with 1 robot and try it out for 1-2 years before they start scaling within one production line before scaling across production lines or across factories. So you are into a multi-year cycle and it requires a very long time and a high investment upfront to get into these customers both on a regional level and on an HQ level. We are seeing some success with this now. Customers actively scaling across factories with the same solution they developed in one factory and now want to transfer to the next factory." [MIR]

- Sales cycles can be extensive, and have also recently been elongated by many customers

"we already talked earlier about the sales process. It's quite long 6-18 months… it's not quick." [Karter]

- In greenfield opportunities there can also be delays to other processes, such as the actual construction

"Sales cycles are anywhere from 3-6 months. Some are longer and this can also depend on macroeconomic factors. And when you're in a greenfield build, there's a longer cycle just because it's a piece of a much bigger project and you can't really define your automation until you know the layout." [Koerber Supply Chain]

SALES WITH HIGH POTENTIAL FRICTION

- The AGV & AMR Robotics sale can be drawn out, especially when dealing with customers that are very new to mobile robots
- Vendors often need to ask customers to make changes to the way their businesses are set up, such as material flows and processes
- Such changes can add significant friction to sales

"We also need to ask customers to change their operation to work with AMR." [Okamura]

"As a vendor, I have a high friction point and I'm doing this island of automation and I have to convince the buyer that this is a really good place to start… with a good value prop... I have to lean in and I'm going to pull every variable that I can in order to make that ROI look great. That probably includes an optimistic throughput target… and then there will be fine print somewhere that says there are lots of things that are out of our control and so therefore… that's one thing the vendors are not taking ownership or responsibility or accountability for." [Christensen Strategy Group]

- Top management buy-in is also paramount as employees working with vehicles may dislike changes required to make AGVs & AMRs effective tools

"I will say that the robots were not very well perceived in the first phase, but as the project comes through and the customer and workers started to feel that actually their workload is getting lower and lower because they need to move less elements. Then they were also starting to see the robots as a better approach." [Moontech]

PREVIOUS FAILURES MAY IMPACT

- Failed projects is not an exclusive feature for robotics, but exist everywhere
- However, such failures may have a greater impact in a relatively nascent industry, such as the AGV & AMR Robotics sector

"Inhibitors might be past project failures. Customers can have long memories and apply one experience with one vendor to a class of technologies. I'm not going to throw a vendor under the bus, but one vendor has had a handful of projects that didn't go as planned. Customers that had been involved in those projects may equate that failure more broadly to the technology category and refuse to consider autonomous mobility solutions as a result." [Koerber Supply Chain]

THE QUALITY OF FLOORS CAN HAVE A HUGE IMPACT ON THE SUCCESS OF A PROJECT

FLOORING IMPACT ON AGV & AMR ROBOTS

- Deploying an AGV & AMR Robotics project can be fraught with difficulties and often seemingly minor issues can be obstacles to successful deployments
- In brownfield environments, the quality of floors can sometimes be a determining factor

"Some floors might have some little rocks or the tiny bumps on the floor. So when the AGV or the AMR is going through the floor they might stumble or get trapped and some other cases. Let's say when you're going to a lift and there's a gap. This is often the case for the older factories, the gap between the lift and the ground floor is quite huge and some of the AGV cannot overcome that." [Anonymous]

- Interviews suggested space is rarely the primary issue in brownfield sites, rather the state of the floor surface

"Space availability is not a huge issue, but for old factories, many of them have floor surface issues and its not so great… most AGVs across the sector, they can't really work on these floors. Sometimes it can be more expensive for customers to replace the whole system rather than building a new factory." [Anonymous]

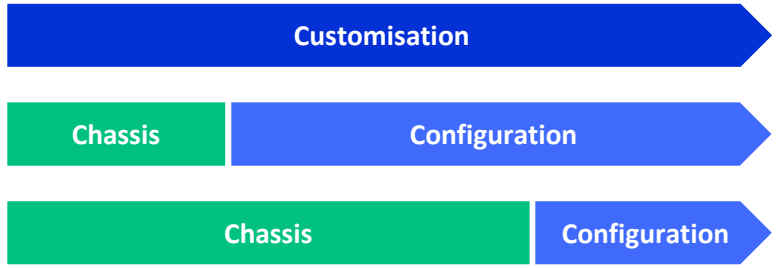
- Replacing or fixing floors could sometimes be an additional cost to projects

EXAMPLE OF CRACKED CONCRETE FLOOR

Image Source: GB Flooring

CUSTOMISATION VIEWED AS A MAJOR INHIBITOR FOR FURTHER GROWTH IN THE SECTOR. SOME VENDORS HAVE DEVELOPED STRATEGIES TO REDUCE OPTIONS

CUSTOMISATION V CONFIGURATION



TAILORING, AN INHIBITOR

- Interviews suggested a high level of customisation of vehicles remained a significant inhibitor for further growth in the AGV & AMR Robotics sector

"I think the biggest inhibitor is standardization. It's very hard to standardize automated forklifts. The reason is because of the dimensions of product you see in warehouses. It seems rather subtle but if you look at pallets and the way you pierce the pallet... first of all you have to fit in physically, but then you also have to detect the load. Depending on the variety of loads and whether you're picking a gitter box or pallets and whether the pallet has no overhang versus 10cm's of overhang… the way sensors perceive the pallet is different which makes it extremely tough. Then you also have safety fields. Depending on the size of the loads, the safety fields may have to adjust. For every project you risk having a different setup of the sensors and you risk of having a different parameterization of the safety fields… that imposes modifications to the vehicles." [Movu Robotics]

"I think the upfront work, kind of like tailoring the solution to the customer… I think that's definitely an industry wide challenge and we run into that a bit… We're not doing custom vehicles like some other AGV companies." [Vecna Robotics]

- Customisation is often quoted as an inhibitor for further growth

FORKLIFT VENDORS, OPTIONS CATALOGUE

- Many vendors of automated forklifts have developed configurable product catalogues

"We have a catalogue of equipment but you can't just order that piece of equipment, it's going to be custom built configurable design." [Muratec]

SERVICEABILITY, THE KEY TO CONFIGURATION

- This has been partly developed to enable these companies to easily maintain and service deployed vehicles and also include components

"We strive for uniformity across our platform as much as possible to allow us to supply spare parts in a much more agile way." [E80 Group]

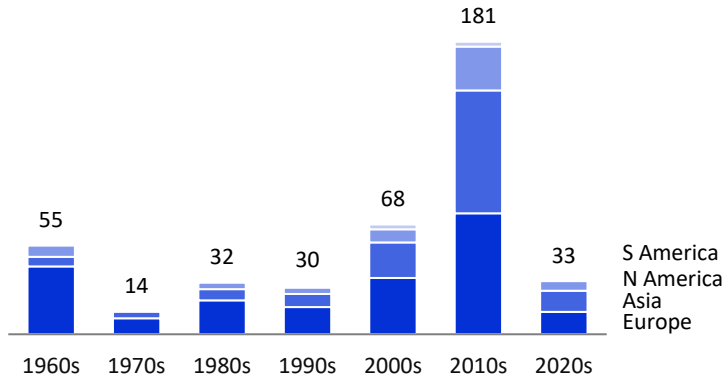
- Moving from customization to configuration was also a matter of competitiveness, something appreciated by the manual forklift vendors

"The successful mobile robot vendors seems to try to get a little bit of mass customization, invented by automotive OEMs, to use as much as possible standard components while still fulfill customers' special requirements. When you have to customize your robots, you have to do it efficiently. Otherwise you will be too slow or too expensive." [Jungheinrich]

"We do a fair amount of customization at a vehicle level. When we talk about customization it could be different fork lengths or maybe unusual mast heights or moving cameras and things like that. It's a strength that we have the possibility to offer this. But it also inhibits growth because it takes time and slows things down." [Toyota MH]

A HUGE INFLUX OF AGV & AMR STARTUPS IN THE 2010s BROUGHT ADDITIONAL FRAGMENTATION AND POTENTIAL FOR CONFUSION FOR BUYERS

ADDITIONAL NEW AGV & AMR SECTOR VENDORS PER DECADE, 1960s-2020s (#)



Source: STIQ Ltd research & analysis
Note: Year company founded, may differ from when added AGVs, AMRs. 1960s include any company added earlier

AGV & AMR VENDOR DEMOGRAPHICS

- This analysis is based on when the company started, not when they added mobile robots to their ranges
- STIQ tracks nearly 500 vendors globally which may only represent 50-75% of all vendors in the sector
- Of these 500 vendors, 44% were founded in the 2010s
- The AGV & AMR Robotics is likely to continue fragmenting partially due to the ease of building vehicles
- Companies could add both AGVs and AMRs with relative ease as suppliers of sensors and software were prolific and the latter actively targetted electric industrial vehicle manufacturers

MARKET FRAGMENTATION = CONFUSION

- Interviews suggested a sharp increase in the number of AGV & AMR vendors in the 2010's led to a level of confusion among buyers combined with far longer sales lead times

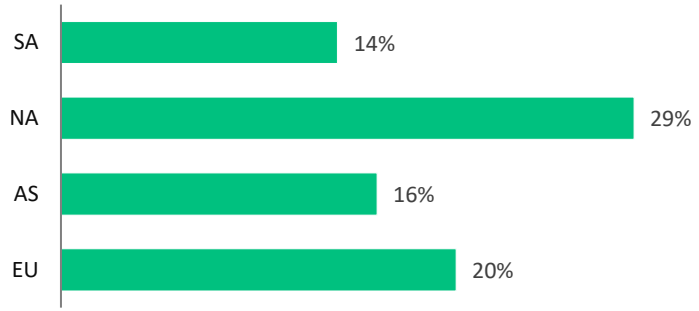
"More vendors have had the effect that it confuses customers about what's out there and how it is different. It has also slowed down the sales process. Before the 2020s you only had a handful of vendors and it was easy for customers to compare. Many of the early projects we simply won because we had a superior product. But now 6-7-8 years later, most products are probably on par with each other and there's much, much more choice in the market." [Robot Center]

- Getting the right AGV or AMR could be confusing even for experienced and knowledgeable buyers

"A fragmented market can be confusing for customers... and let me give you a few views on that. It's very difficult for the purchasing departments to look at. Because bigger companies have innovation managers or automation managers and some of them know the space really well. But even they are in a dilemma. At the end they want something new and fancy but at the same time need a working solution to avoid losing their job. Their thinking... How innovative can I decide without risking to be fired if it doesn't work." [Wagner Fire Safety]

- STIQ has held plenty of conversations with global enterprises which confirms this
- **If you want to have a conversation with a STIQ analyst on the AGV & AMR Robotics market, send us an email to organise a confidential chat**

SOFTWARE VENDORS AS A SHARE OF ALL VENDORS (%)



Source: STIQ Ltd research & analysis. Companies offering software as a standalone product

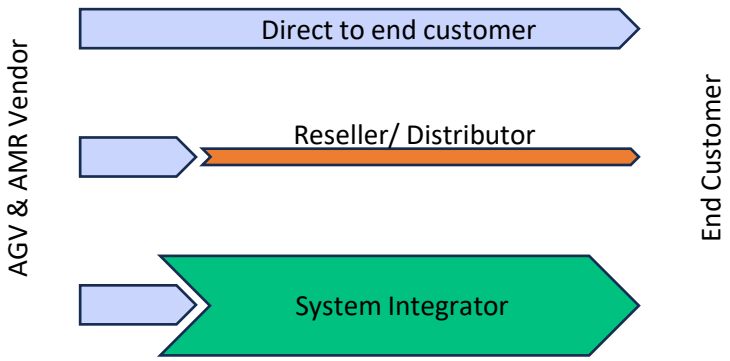
- Buying mobile robots can also come down to trust, depending on processes that are being automated

"The purchasing process is very long because there's so many vendors to choose from. Everyone is promising the same and it's really a trust thing... the bigger companies have innovation managers to monitor the space. But the smaller companies might be even more confused." [Wagner Fire Safety]

"In the end price is one decision point. But the overall trust that it's even going to work is also significant especially when you work with critical processes." [SAFELOG]

MOST AGV & AMR PROJECTS DIRECTLY BETWEEN VENDOR AND CLIENT. RESELLERS FEATURE, BUT DISTINCT LACK OF SYSTEM INTEGRATORS

AGV & AMR DISTRIBUTION STRATEGIES



Source: STIQ Research & Analysis. Illustrative only. Individual cases may differ

LACK OF AGV & AMR SYSTEM INTEGRATORS

- There is a lack of international system integrators with access to global companies in the AGV & AMR Robotic sector (note -> excluding e-commerce type applications)
- The primary reason for this has been a combination of a fragmented market with one where manufacturers also serve end customers
- Some manufacturers had focused on a certain industry sector (or sectors) and turned into Specialists and/or Solution Vendors
- If you are interested in how this has evolved, please contact STIQ for a conversation

SYSTEM INTEGRATORS OFTEN LARGE PICTURE

- Mobile robots can often only be a smaller part of a larger automation project which system integrators are typically used to manage, bringing in many different types of automation

"We're looking at it not from a narrow scope of, hey, I can sell 10 vehicles to this customer. We're looking at, I can help this customer solve these very challenging problems with a portfolio of solutions that we can bring in, Balyo being a function of that function." [Koerber Supply Chain]

"Mobile robot are often only part of that big puzzle with processes and integrations. I guess that's why companies with internal teams have more success when they understand the whole process by themselves and do their own integration." [MIR]

GLOBAL CUSTOMERS DEMAND LARGER SIs

- Global companies often want to work with larger system integrators with capability and resources across international locations

"Especially when we talk about these large global accounts… they also want large system integrators that can help them integrate robots. And that is something we're trying actively to develop ourselves, finding these large regional players. Cross border players that can help implement our solutions at these large accounts. That is definitely missing and that's not fulfilled… these partners are hard to find. But what we also see is customers with the biggest success are the ones who have integration teams internally and they skip the integrator." [MIR]

SAMPLE PARTNERSHIPS (NOT EXHAUSTIVE LIST!)

Vendor	SI Partner
Balyo	Korber Supply Chain
Fetch Robotics	Barcodes Inc
Otto Motors	Honeywell
SAFELOG	TGW

Source: STIQ Research & Analysis. Not exhaustive!

THE INDUSTRIAL ROBOT SI ANGLE

- Industrial robotics system integrators have looked at the AGV & AMR opportunity, but also noted that there were more variables that can impact projects

"When you look at these industrial robot integrators, they have certain milestones that they can hit in projects and then they can pretty much hand it off to the customer. With mobile robots it's a lot more challenging and so… you get the sale, you start looking at it from a P&L standpoint and it looks good… let's get it implemented. But then it's just… there's so many more variables that come into play with mobile robots and that P&L may quickly become challenged." [A39]

SYSTEM INTEGRATORS ARE ONLY ONE DISTRIBUTION STRATEGY. NASCENT SIGNS OF AN EMERGING SI LAYER

AGV & AMR DISTRIBUTION STRATEGY

- Some vendors partnered with multiple distributors to reach a global market
- However, many smaller distributors may sell <5 robots per project and often do not have consulting experience

"Small integrators always get the most difficult projects and so on. The biggest integrators with the highest margins are always given the larger projects." [Versabox]

- In recent years, AGV & AMR vendors have increasingly partnered with System Integrators capable of running multinational projects
- Interviews suggested the market may still be nascent for such System Integrators but also that some vendors should be willing to give up larger projects to partners

"It might not be that interesting yet for some of the global integrators to go into AGV & AMRs yet because the projects… it's still a bit nascent, and the project sizes are perhaps not there yet." [MIR]

- Selling AGVs & AMRs required a higher level of knowledge for sales staff

"One of the difficulties is the price range of this item which is very different to an ASRS or conveyors. And our sales team is not familiar with selling this kind of item. The price of this kind of robot is only ¥1m, but a conveyor system could be maybe ¥100m-1bn. That's the most difficult part… our operation is not familiar with selling these kind of projects… so that's why we also need to develop our business model." [Okamura]

"Some vendors in the AMR space want to own it all. They want to own the data, they want to own the software, they want to own the robots… they want to take all of the margin stack and that value chain, but they're not going to get it. That's going to get eroded and some of the vendors have to embrace and understand that… and frankly capitulate. They may have to approach an integrator as a channel as opposed to doing everything direct and trying to own the whole thing." [Christensen Strategy Group]

A DIFFERENT TYPE OF RESELLER REQUIRED?

- Some forklifts vendors have realised the best reseller for AGV & AMR Robots is not always their own sales org

"We realize it is quite different distribution for AGV & AMR, not like the traditional forklift distribution systems. Like other robotics companies we are now searching for some suitably qualified distributors overseas. We find it very interesting that the distributors, which sell manual forklifts, the people in this kind of distributors know many customers and they are good at hardware. But we just realized the good distributors for AGV may be those that come from the software company. Because the software is really the key for the AGV business… the hardware will be working or will function well under the good software structures and the automatization stuff you have to synchronize with the customer side, the fleet manager system. Like the ERP systems." [Hangcha]

SIGNS OF EMERGING AGV & AMR SIs

- There were signs that a new System Integrator layer was forming, possibly as a response to the increasing commoditization of mobile robots

"Our value proposition is to set up and integrate mobile robotic projects. That means we use two technologies – AGV and AMR. We are currently integrating a 27-AMR project in Spain using a Chinese brand." [Moontech]

- Some of the intralogistics software companies also appeared to be turning into kind of consulting firms for AGV & AMR Robotics

"Our approach, which is a bit unconventional, involves initially designing a digital twin for our customer's intralogistics processes. Together with the customer, we analyze it. If we find that introducing AMRs would be beneficial to the customer, we then begin thinking about which model and which vendor would be the best fit." [Arendai]

"A lot of our clients are just starting their journey towards automation. They do not have different robot systems and we are often the first one. Sometimes we have a partnering approach right away and then they approach us with the idea of integrating robots." [idealworks]

ROBOTS VIEWED AS EXCITING TECHNOLOGY MAY HAVE DISPLACED MARKETING FOCUS. SOME SIGNS OF INCREASING AWARENESS OF PROJECT COMPLEXITIES

PROMOTING ROBOT EXCITEMENT

- Interviews appeared to suggest some of the marketing for AGV & AMR Robotics had created a heightened level of excitement of robots
- However, some of this also appeared misplaced and had driven up expectations of unrealistic project simplicity

"I think some customers have an expectation that it is a very quick process. Like we exchange some emails and four phone calls, one visit and it is done. But it is the whole integration and people having to reshape their entire processes again, not based on humans. Expectations are often different." [Karter]

"There are a lot of reprocessing requirements with an AGV or AMR which you have to change your business for… and you often have no clue how long it takes. AGV is not a new technology, it is already here since the 1950s. But the expectations today… that's a different story." [Karter]

- Robots were perhaps easier to market as they were viewed as being "sexier" than more traditional automation such as stacker cranes and conveyors

"Some of these facilities are just looking to try to offload forklift truck drivers and people that push carts around all day. They typically don't really know what goes into an AGV & AMR deployment. It's very true that it's hard to find that right customer. You get a lot of interest in mobile robots. It's a new sexy technology that people like the concept of but often don't fully grasp, understand." [A39]

"With all types of automation projects you need to qualify your project and see if it's realistic to invest in an automated system. With AGV & AMR projects, there is a disproportionally high rate of unqualified opportunities because people are intrigued by it, more so than they are intrigued by a conveyor or a crane." [Movu Robotics]

HOWEVER, SIGNS OF INCREASED AWARENESS

- Despite all the unqualified inquiries, there were positive signs that customers were beginning to take mobile robots seriously with innovation teams, etc.

"Finding those customers with automation experience… We had a couple of them with engineering staff on site… still, a lot of these Fortune 500 companies they're starting to put together robotics teams. That's a good indicator that these guys are going to be able to understand and support what goes into an AGV & AMR project and help us out when things go up and down the road. That was where we were successful with customers that had those kind of teams and groups." [A39]

- Early trials were also leading to growing awareness of AGV & AMR Robotics

"But there are also still many customers who are basically still in the testing and playing around phase and trying to see, OK, can I standardize enough? So do I have enough benefits? Am I running in two shifts, 3 shifts or one shift makes a difference? So you still have a lot of that kind of early learning process going on. But you do see that the customers in average in the past five years are much more educated. Because many of them have done their first trials." [K. Hartwall]

AGV & AMR EDUCATIONAL RESOURCES

- What business are you:
  - I'm potentially adding AGVs and/or AMRs to my factory and/or warehouse: MHI MAG / SAFELOG
  - I'm adding autonomy to our electric trucks/vehicles: KOLLMORGEN

AN INSIDER'S VIEW ON MARKET INHIBITORS: FOUR KEY RISKS TO ANY AGV & AMR ROBOTICS PROJECT

FOUR KEY RISKS

- One interview succinctly described the challenges or inhibitors for driving faster growth in the AGV & AMR Robotics sector

"I see four customer risks and they're in sequence: Selection, Capital, Operating and Adaptation… All four of those things are, to me, what's slowing the sector down."

- STIQ tracks c.500 vendors in the global AGV & AMR Robotics sector, a number that has increased year on year in the last 4-5 years

"Selection risk means there are too many vendors. I don't understand the differentiation. I don't know who to buy. There isn't a clear market leader and that stops me in my tracks." [Christensen Strategy Group]

- As with any other CapEx project, there was always a risk that promised ROI will not materialise, especially when the cost of capital increases
- For customers that are AGV & AMR novices this could add additional risk dimensions

"Capital risk means I'm going to put out capital. Especially when capital is expensive for a speculative future payback. Tying in with the selection risk if I'm not really sure that it's going to work and I'm putting capital out for a payback that might happen in the future. I've now 2X'd my risk for both of those factors." [Christensen Strategy Group]

AGV & AMR PROJECTS: FOUR KEY CUSTOMER RISKS

ADAPTATION
- Does the system encourage continuous improvement?
- Does the customer have psychological ownership of the system?

OPERATING
- When vendor leaves, do the customer's staff know how to operate system?
- Relying on system when there is peak demand

CAPITAL
- Capital risks
- Speculative payback

SELECTION
- Too much choice, too many vendors
- Little difference between vendors

Source: Christensen Strategy Group, website. Graphics adapted by STIQ Ltd

- Once procured, integrated and deployed, will staff be able to operate the system and not interfere with processes during peak
- Will staff interfere with processes rendering efficiencies from the system incomplete?

"Operating is where a lot of pilots fall down. When the vendor leaves, am I going to be able to realize the ROI? Can my people actually operate this properly? Or when we get a spike in demand, do we lean into these robots, or do we go back to the old way because we know we can get through it that way… and we just don't trust these robots." [Christensen Strategy Group]

- A final important inhibitor is where customers are required to take ownership of a system
- This can be an issue where customers buy a system for specific tasks versus a solution

"Adaptation… does this encourage or hinder me for continuous improvement? This ties back to usability. If I have ownership, not commercial ownership, but psychological ownership over the technology. Can I have it do the things that I want it to do. Then I have confidence in adaptation because I know we should be changing our process a little bit this way and I know that I can apply the technology to execute that change. But if I don't have the confidence in the operating side, I don't think that I'm going to be able to apply it to the adaptation, which means that I have this shiny new toy that is actually preventing me from executing continuous improvement… which is really bad." [Christensen Strategy Group]

IS THE AGV & AMR ROBOTICS SECTOR SET UP FOR DISRUPTION? PARALLELS FROM THE INDUSTRIAL ROBOTICS SECTOR

AGV & AMR DISRUPTION IN THE CARDS?

- Interviews suggested there were two potentially important parallels from how the industrial robotics sector developed
- Firstly, prior to Fanuc's entry in the late 1970's, most industrial robots were heavily customised or largely custom made, made to order

"In our business we have to offer customization. I've heard this over and over again until there is a disruptor in the marketplace that figures out how to get around that. In the robotics business, ABB and KUKA and others were convinced that without customization, no one will sell one single robot. And then FANUC came along and just sold standard robots and they became the biggest player in the world. So I think it's a mindset, you have to sell what you have and not just ask for specials." [Toyota MH]

- Secondly, industrial robots relied on the automotive sector for many years, until the electronics sector started buying robots

"For the industrial robotics industry, it was for many, many years stuck at a certain level because we were 100% relying on one vertical - automotive. But all of a sudden, we started selling industrial robots to F&B, to electronics, and that's really when the pivot happened… when the electronic companies started to buy robots we went from - and I can only speak for ABB - hovering around 15-20,000 robots per year and all of a sudden in a few years we went up to 50-70,000 robots and we were targeting 100,000 when I left. So I think it's about timing and getting the right applications for specific segments." [Toyota MH]

- There was also some thinking the AGV & AMR Robotics sector would reach critical mass in a not too distant future
- However, the wider ecosystem also appeared to lag behind, partly due to relatively recent developments in SLAM technology

"I think AGVs & AMRs is just one of those things that just takes some time in the industry to get some traction. Robotic arms were created 30-40 years ago and they're still just catching on. It takes some time to get to a point where people fully understand how to use the technology. For example, we struggled with getting into the education system when I worked at a vendor. Talking to universities, community colleges… they are not always the best with staying up to date on technology. You go to these colleges and they're dealing with robots that are 20 years old. For them to get a whole new curriculum and go through all that takes years to get approved and so… But there are some schools that are diving into the kind of factory of the future classes with connecting different devices. I just think it takes some time and it's not an easy fix." [A39]

OTHER SECTOR DISRUPTION PARALLELS

- Other stakeholders also viewed other industry disruption parallels

"This is like back in the old days of the many different phone manufacturers… until a super platform comes and just completely disrupts those discrete solutions. I think it's going to happen in industrial automation as well." [Cyngn]

EXAMPLE OF INDUSTRIAL ROBOTICS

Images: brands own, source

INDUSTRIAL ROBOTICS CAVEAT

- Readers should note that two of the interviewees on this page have an extensive background in the industrial robots sector which may influence their views

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RECOMMENDATION TO START SMALL AND LEARN IN A STEP-BY-STEP APPROACH

THE STEP-BY-STEP APPROACH

- One approach can be to start with a single or a few vehicles, but such a project has to, and should be coming from, the top, or with senior buy-in
- Without senior buy-in, such a project could simply end up with a robot in the corner collecting dust

"The strategy was to iterate on an MVP approach. Our customer started with one AMR, checking tech/robots from China. This started in Nov 2022. The COO at our customer saw it working and said he wanted just AMRs to substitute the manual-driven workflows. We integrated 2 more and used 3 AMRs on another testing phase. After that we integrated another 24 AMRs and remove standard forklifts." [Moontech]

- Once you have the robot/s it is important to include them in your work processes or workflow

"Do it step by step and learn with your team how you can improve, how you can do things better and then you can scale up. Scaling with a robot is not that difficult, you just add another robot to the system. The fundamentals are already there. You have the base already, you have the map, you have the picking points, dropping points. You have the chargers, you have the door integrations. You just add a new robot and the system says instead of one I have 2-3-4-5 robots and you divide all your missions. Scaling up is not an issue. It is the getting into the work process that is the difficult part." [Karter]

- This is also when a customer may realise there are things that need to change to accommodate the robot/s
- There will also be important conversations with other team members to explain how the robot will work, if it will make their lives easier, if it will change processes for the worse (subjectively), etc.

"My advice to customers if they really are interested. Why don't you start simply with 1-2 and just take time and learn the robots. Because I cannot tell you at this moment what you have to change in your processes, because if I have to do that, then it takes 6-12-18 months to evaluate and go into all the details. And then we have to think all the processes and what this and what then and we have to talk to everybody, every department who is involved, etc." [Karter]

- It may take 6-12-18 months to become conversant with a robot or robots but customers may finally realise they perhaps require other forms of automation

A POSSIBLE AUTOMATION JOURNEY

- Some customers are on a journey of increasing automation, from a very simplistic setup, perhaps with a few mobile robots
- Then moving into different areas or adding new workflows with a new set of robots

THE STEP-BY-STEP APPROACH TO AGVs & AMRs

Source: STIQ Ltd research & analysis

"Our customers typically have this journey where they are increasing in automation and they have started with very simple systems. And then they maybe introduce some more automation, such as increased storage volumes or increased dock door delivery or more output on machines… and that's the journey everyone is going through. Our challenge is to offer A-Z everything in between and that's the suite we're trying to build to accommodate all the sales that we have in the group companies." [Toyota MH]

WORKING WITH A STRONG PARTNER HELPS

- Finding and working hand in hand with a strong partner can be paramount

"What we have found is that the best way to make our customer grow is to make a good marriage between a strong end customer and a strong AGV maker." [BlueBotics]

- However, such a relationship should be mutually beneficial and be clear from day one with clarity over call out charges, who is responsible for what, etc.

RECOMMENDATION TO GO FOR A LARGER PROJECT WITH CONTRACTUAL PERFORMANCE BONDS OR THROUGHPUT GUARANTEES

RISK AVERSION, INHIBITOR FOR CUSTOMERS?

- Risk aversion may be an inhibitor for both vendors and buyers
- For customers, going slow may mean that projects are drawn out, there may be creep in KPIs and project management teams may be replaced with additional complications
- On the vendor side, it may be nearly as resource intensive to do a small project as a much larger project for the same customer

"Some customers are risk adverse and approach robotic vendors asking to start a small pilot with 1-2 trucks. But a 1-2 truck pilot project ties up a lot of resources. So vendors are stuck with small projects rather than customers that take a leap of faith and say OK, we want to automate seriously - especially larger clients with targets of 20 plus automated DCs. They should go for one DC and start with 10 plus trucks, because you can only look at how the bigger system is performing at this level really. More risk, but way faster than doing 2 truck, then 5 then 10 truck pilots before being assured the vendor does the job and really no one being happy with the slow progress." [Wagner Fire Safety]

AGV & AMR CUSTOMER RECOMMENDATION

- Interviews suggested customers should be very clear with their performance requirements and possibly even request a performance bond on throughput

"What I would do as a customer… so if I were to buy AGVs now — instead of testing one vehicle, I would very clearly specify what the system is supposed to do in my environment, spend more time on these detailed requirement specifications and performance characteristics you seek, than discussing the vendors marketing materials / features. And most importantly: create the paperwork with the same mindset. If a customer wants to go really above and beyond for very large projects that justify the extra cost, you can even have the vendor provide a performance bond to guarantee that. That way you make sure that even though you go bold and go with 20 robots rather than a single vehicle, the risk for the purchaser is minimized. Customers just need to make very clear what exactly it is they want, which only works if the language is not vague but precise on all environmental aspects and performance metrics. If the vendor then chooses to quote it, make them contractually bind to it." [Wagner Fire Safety]

- However, this also requires customers knowing what it is they are asking for and having a level of knowledge about what is involved in a mobile robotics project

AGV & AMR VENDOR RECOMMENDATION

- Both vendors and customers should be up front with potential for additional costs and make sure contracts are structured accordingly

"It's a big learning curve for facilities that are deploying AGVs & AMRs. And there's always going to be things that come up that require somebody to go on site and it's got to be structured properly from an integrator standpoint. They need to be up front with customers and say there's going to be some bumps and bruises along the way, but it's not necessarily going to be our fault. There will be things from a personnel standpoint, training standpoint that may cause issues and we'll have to bill you for those trips and that service. But it's hard to have that conversation up front when you're trying to get the sale. But you got to level and set those expectations. I think also just the inability to fully wrap up the project and say, hey, this project's over, it's in your hands now… Call us if we can help out and come on site and bill for that. But otherwise… you know, we're done." [A39]

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SUPPLY CHAIN DISRUPTION EASED IN 2023. SIGNIFICANT DISRUPTION IN 2021 & 2022 CREATED MARKET RESEARCH OPPORTUNITY FOR KEY COMPONENTS

SUPPLY CHAIN STRESS INDICATION (LEAD TIMES)

Year	Stress Level	Key impact/ component focus
2021a		• Random components + higher prices
2022a		• Safety components (EU, NA)
2023e		• Sporadically longer lead times
2024f		• Return to normal lead times

Source: STIQ Research & Analysis.
Key: a=actual, f=forecast

2023: NO MAJOR SUPPLY CHAIN ISSUES

- Interviews suggested the disruptive supply chain issues experienced in 2021 and 2022 had dissipated

"We have not had any extraordinary supply chain issues this year." [MIR]

"From what I'm seeing, supply chain disruptions, it's perhaps used as an excuse today more than a factor. Just broadly speaking, it doesn't seem to be as impactful as it was two years ago." [Koerber Supply Chain]

- However, there also appeared to be some sporadic problems or difficulties

"Cables, is a big issue. Copper and wiring harnesses… a lot of that work came out of Ukraine." [Bosch Rexroth]

- Some interviews hinted that a few AGV & AMR manufacturers still experienced problems

"Some customers still have supply chain problems." [BlueBotics]

PENT UP DEMAND DUE TO DISRUPTION?

- There appeared to be some level of pent-up demand from 2022 due in part to the supply chain disruption challenges

"The supply chain issues that we had over the last 18 months or so really has extended things. So we're seeing a little bit of an exaggerated… if we say 'pent up demand' as we exit the supply chain tightness." [JBT Corp]

- For component suppliers, the market may not return to growth until 2024 as there was a level of panic buying and hoarding of components during the worst part of supply chain disruption

"When AGV vendors found out there's longer lead times, they also ordered more. A lot of those components have been piling up because they have now been delivered. So that's what's driven down component orders. It should level out maybe in 0.5 year… that's the background." [Bosch Rexroth]

SOME COMPONENT VENDORS NO IMPACT

- A few vendors did not experience any supply chain issues whatsoever during 2021 and 2022

"We were expecting to have a bigger negative effect from component shortages also in 2023. But we haven't seen that at all to the extent we thought that we would. We never had the problem with on-time delivery of our hardware. Our customers were able to buy it the whole time." [Kollmorgen]

THE SAFETY COMPONENTS

- Safety components were in very limited supply during large parts of the pandemic and were also relatively monopolised by very few vendors
- This situation caused a bottleneck for many AGV & AMR manufacturers, but also created an excellent opportunity for market research for competing suppliers

"We had tons of customers asking us for an alternatives… plenty of requests for safety Lidars, for example… so we could see how much of a need there was for these products." [Pepperl + Fuchs]

ADDITIONAL SUPPLIERS SIZING UP MARKET

- As the AGV & AMR Robotics sector grows and matures, there will be more interest in the sector from a variety of vendors

"We kicked off an initiative to address AGV market in past years, we found the value we can bring in with our offerings, which help this industry to future-proof data communication systems." [HMS Networks]

COMPONENT CONSOLIDATION COULD ALSO DRIVE COMMODITISATION IN THE AGV & AMR ROBOTICS SECTOR. SOME VENDORS KEEN TO KEEP CONTROL AT DEEPER LEVEL

COMPONENT CONSOLIDATION

- Component consolidation was a natural development to incorporate more functionality

"Component consolidation helps to the final customer. Because the final customer or AGV vendor has to take responsibility for the vehicle and the complete system. In the end, if you have a better components, it's easier for the customer and if you integrate more of the functionalities, it's easier for the customers." [Mobotic]

- Some vendors focused on additional safety features which could make certification easier

"We decided to bring the functional safety and to build the wheel drive with all the safe motion integrated in the drive system... In Europe you have the CE marking now which is very strict. You need to make sure that your AGV fulfills ISO 3691-4. This is much easier when your components are already certified… you have no specific safety assessments to redo. So that can be a huge time and cost saving." [ez-Wheel]

- Increased focus on consolidating safety features combined with a more international focus for many Chinese vendors had opened up opportunities

"We are starting to work with AGV manufacturers in China. Because the market is not growing as expected. And they are looking to export and for exporting then it is a different game. They need more safety, they need more performance. Other type of requirements." [Synapticon]

CONSOLIDATION, NOT FOR EVERYONE

- However, not all customers were interested in such functionality consolidation and preferred to have their own set up

"It depends on the customer. Two weeks ago, I was at a vendor and they were saying they don't want to buy a black box. We want to have the control over it. We want to do exactly our own kind of integration. But our integrated solution is cheaper and instead of having the motor, the wire harness and all the technical aspects for that… the thermal perspective… all the heat generating components are outside of the vehicle… so motor control electronics, the power electronics, it's now on the side of the vehicle, not inside the main compartment. So that's a technical advantage." [Mobotic]

- Maintaining a deeper level of component control could also be a way to resist an inevitable move towards increased commoditisation of vehicles

"In the end these mobile robots will become a commodity and it's going to be more of a price battle on the product level. This was mainly on the project level until now. But this will change and it's boiling down to the robot price in the end." [Mobotic]

COMPONENT CONSOLIDATION – LIKELY FUTURE WITH SLAM EMBEDDED IN SENSOR?

Image source: SICK (link)

LIKELY FUTURE DEVELOPMENTS

- AGV line guided navigation technology is currently embedded in a sensor
- AMR or SLAM type navigation, on the other hand, is currently supplied separately, i.e. sensors, computing hardware and software are supplied separately
- Many sensor companies are also developing SLAM components and one likely future may be to embed such software in a sensor
- However, the share of SLAM navigated or AMR robots may have to grow significantly before such an embedded solution will be ready for market

- Did you know STIQ will publish a new report on the "Future of Warehouse Automation" in 2024? Sign up to our newsletter to be updated on this publication

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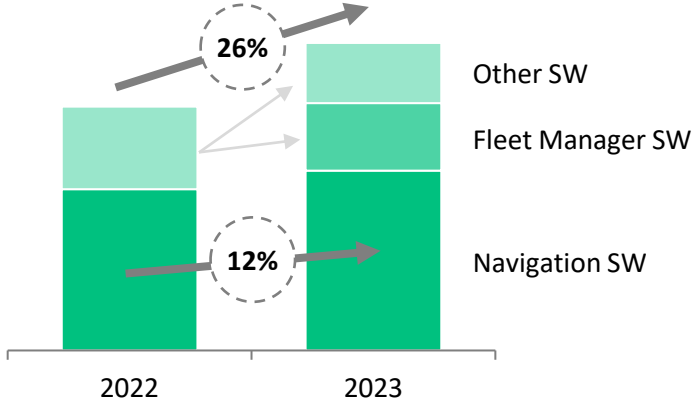
INCREASING FOCUS ON SOFTWARE THROUGHOUT THE AGV & AMR ROBOTICS SECTOR. FORKLIFT MANUFACTURERS SHOWING GREAT INTEREST

AGV & AMR SOFTWARE VENDORS GROWTH, 2022-2023 (#)



Source: STIQ Research & Analysis. Fleet Management companies not tracked in 2022.

INCREASING FOCUS ON SOFTWARE

- There was a growing focus on software throughout the wider AGV & AMR Robotics sector with an increased level of activity by multiple stakeholders
- The two primary software segments in the AGV & AMR Robotics sector were **Navigation Software** (SLAM) and **Fleet Management tools**
- There was also increased activity focusing on other parts of the AGV & AMR Robotics sector

GLOBAL FORKLIFT VENDORS ACTIVE

- It was not only startups that were active in the software genre, but also the global manual forklift vendors
- These companies were very active and showed a greater interest in the AGV & AMR Robotics sector in recent years, possibly due to accelerated growth rates during Covid
- Most of the forklift manufacturers' software activities appeared to be aimed at setting them up to attack the AGV & AMR Robotics market more seriously than perhaps previously

"We decided to consolidate all the knowledge, especially in order management and fleet management into one company which is T-hive. We've used a unique model, which is to work together with all the group entities that have already made, for example visualization, simulation, etc. softwares. So we have worked on a beehive to use all these assets that we had in the group to blend this into one solution." [Toyota MH]

- Strategies to become more software focused have included M&A approaches
- For example, some more hardware focused companies, such as forklift vendors, appeared to have acquired software vendors to potentially become more competitive

"And we of course want to keep our customers and provide them with the solutions they need in future." [Jungheinrich]

- However acquisitions and different business units spread in different countries can often lead to duplication across various software
- Interviews suggested part of these strategic initiatives was to consolidate software packages

"We're not end-customer facing. We are making a solution that is used by all entities in the respective BU's and we make sure that it is developed once and used a lot of times. That comes with some complexity. But the advantages and collaborations are way higher. So we want to remain using our local brands rather than having a new brand or a new sales company." [Toyota MH]

USER INTERFACES HAVE RECEIVED ATTENTION

- Interviews also suggested a concerted effort to improved user interfaces (UIs) to enable non-experts to also manage basic changes such as re-routing, etc.

"Our product is a toolbox. If you want to use the whole toolbox, you need to be an expert to get the most out of it. To bridge that gap, we've launched a new product that helps those without any previous experience to do a really good layout. You no longer need extensive working experience with our toolbox to manage the system at a good level. That's been something that has been very helpful to many of our customers." [Kollmorgen]

ACTIVITY CENTRED ON NAVIGATION AND FLEET MANAGEMENT, BUT OTHER TOOLS ALSO IN DEVELOPMENT

ADDITIONAL AGV & AMR SOFTWARE

- Other technologies that were relatively frequently used in the sector included teleoperation

"We have the ability to teleoperate our vehicles if we need to. What we do as part of our whole GTM model and our RaaS model is there's SLAs affiliated with our system. And whenever robots do encounter these day-to-day issues we can dial in and solve many of the problems remotely." [Vecna Robotics]

- Robot management tools was another popular genre

"We talking to some big multinationals and they have 500 AGVs and AMRs around the globe. But they don't know if the robots are used 20% of the time or 80% of the time, there's absolutely no knowledge about that one." [Waku Robotics]

- Others had produced robot creation tools

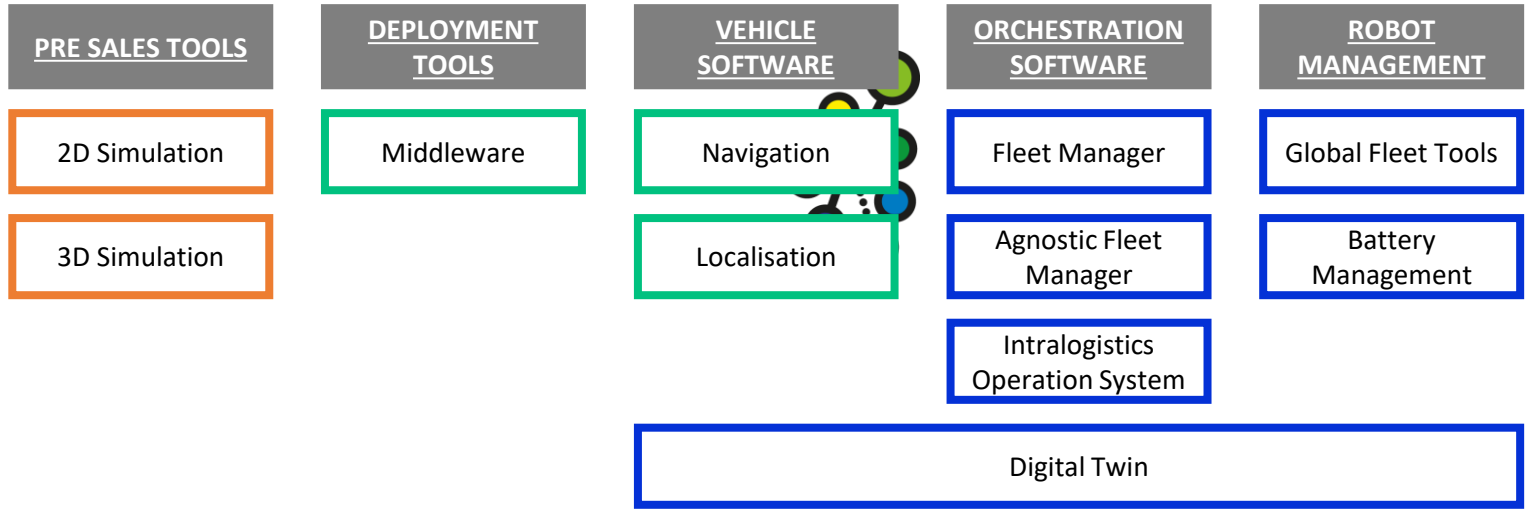
"We have a software which is used by customers to build their robot. It's like a plug & play idea for customers who are thinking about building their own mobile robot." [SEER]

- There were also activities in area monitoring

"Some clients use our system, which is a camera in the ceiling that looks down to detect if a location is empty or occupied. This information goes into our fleet manager. Each shelf represents one convenience store's replenishment." [ForwardX]

- There are also activities in WES which overlap with Fleet Management tools – download STIQs report on WMS Software for a more elaborate explanation on WES
- STIQ 2023 WMS Software report (link to download page)

SOFTWARE ACTIVITY IN THE AGV & AMR SECTOR (NOT EXHAUSTIVE)



Source: STIQ Ltd Research & Analysis

DEPLOYMENT TOOLS

- Some vendors had been working on deployment tools, making this process easier for non-experts

"One of the most difficult parts of the AGV system is to design the splines. Everyone has their own tooling how to do this. We spent a lot of time on spline generation methods. So depending on which navigation vendor you use, it still makes the correct splines for you. The only thing you have to do is to make sure it is loaded on to the vehicle. That's an asset that we use a lot." [Toyota MH]

- Whilst other software vendors had focused on making it easier for stakeholders to get an overview of their fleets of robots, either as OEM, Distributor, System Integrator or end customer

"The USP of our software is different depending on who is buying. For OEM's and integrators, it can be about giving cleaning reminders to end users, getting analytics on service costs as much as spare parts, and asset management. If they use a batch of sensors and they want to understand which batch it is... That can allow them to do maintenance or repairs or exchange of parts, on the basis of the actual usage." [Waku Robotics]

PRE-SALES TOOLS, 3D VISUALISATION + VIRTUAL FACTORY. LIMITATIONS OF SIMULATION TOOLS

3D SIMULATION 'PRE-SALES TOOLS'

- STIQ interviews suggested there was a reasonably high level of activity in developing 3D simulation tools
- Whilst these provided little functionality in terms of 'simulation', they appeared to be highly appreciated by customers as it allowed them to visualise what a mobile robot might look like in their facility

"No one is really asking for 3D visualizations, but from a marketing/sales perspective, it showcases a lot better. Just like if you go online to purchase a car and add accessories to it. People are very visual, so visualizing the work in your warehouse provides a better understanding of what you're getting versus a proposal or a 2D image." [Muratec]

- Such tools were not 100% replicas of existing facilities, rather they used key measurements, etc. to contextualise robots within the environment

"This is not a 100% replica of the actual facility, we're only trying to give them a good idea of the 3D environment with 3D robots." [SEER]

- Providing an exact 100% digital 3D copy of a facility was very demanding

"We spend a lot of time on this 3D visualization part. At this moment its too difficult to make these kind of 3D point clouds, you have to stitch them together. That takes tremendous amount of time. 3D is mainly used as a sales tool." [Toyota MH]

VIRTUAL FACTORY

- There were also developments overlapping with simulation and 3D tools and fleet managers
- Many of these more advanced tools also crossed over with a growing level of consulting

"Hardware and navigation is a commodity. If you visited Logimat you saw there's plenty of suppliers… We decided to invest in this virtual factory software. This solution has allowed us to discuss processes with customers instead of focusing on autonomy and mobile robots." [Versabox]

LIMITATIONS OF SIMULATION SOFTWARE

- Interviews suggested nearly all vendors use simulation software, but this was nearly always different to conditions on the ground, in real life

"Simulation and testing has one problem, you kind of search for the problem that you already know. The real world is challenging with the stuff you don't know." [SAFELOG]

"We use simulation, but when you get to the floor level and you see that not everything is as neat and tidy as in a simulation environment... Because while we can simulate lines going up and down and products changing and so on. When you're in the real world, you start to see upset conditions occurring much more acutely, and so that's really when you need to tune your system to make sure that it can handle those moments of difficulty. It could be that the production line backs up for some reason. It could be that there's a winter storm and they're not able to ship things and the warehouse fills up." [E80 Group]

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THE MANY DIFFERENT NAVIGATION TECHNOLOGIES FOR AGV & AMR ROBOTS OFTEN CAUSE ADDITIONAL CONFUSION AMONG BUYERS

AGV & AMR ROBOT NAVIGATION TECHNOLOGIES

	NAVIGATION TECHNOLOGY	STRUCTURED WORKFLOW	UNSTRUCTURED WORKFLOW	LOCATION TECH	ACCURACY	COST	OBSTRUCTION AVOIDANCE	VEHICLE TYPE	COMMERCIALLY AVAILABLE
AMR	*Neural SLAM*	*Next gen technology (further R&D expected)*							*2020's ?*
AMR	VSLAM	↑	↑	Visual Camera	↗	↑	Possible	F/T/M	2010's
AMR	SLAM (3D)	↑	↑	3D Lidar	↗	↗	Possible	F/T/M	2010's
AMR	SLAM (2D)	↑	↗	2D Lidar	→	↗	Possible	F/T/M	2000's
LGV	Laser (reflector)	↑	→	Reflectors	↑	↗	Possible	F/T	1990's
AGV	Datametric	↑	→	QR Markers	↗	↘	No	M	1990's
AGV	Magnetic	↑	↓	Magnets	↗	↓	No	M/T	<1980's
AGV	CAD	↑	↓	CAD map	↗	↘	No	M/T	<1980's
AGV	Optical	↑	↓	Tape	↗	↓	No	M/T	<1980's
AGV	Induction	↑	↓	Cable	→	↓	No	M/T	<1980's

Source: STIQ Ltd Research & Analysis. Note that multiple vendors also deploy odometry and/or other sensors to localise their vehicles
Vehicle Type: M=Mouse, T=Tugger, F=Forklift

DIFFERENT NAVIGATION TECHNOLOGIES

- The many different navigation technologies used in AGV & AMR Robots can often be an additional source of confusion for buyers
- It is often the environment where mobile robots were going to operate that determined the best navigation technology to be used
- Furthermore, ROI could also vary between different technologies

NO OUT-OF-THE-BOX FUNCTIONALITY… YET

- Importantly, none of the navigation technologies available today offered an out-of-the box functionality
- People were still required to visit sites, measure, check H&S requirements, analyse workflows, prepare the maps, etc. for robots to work

"Remember in AGV & AMR, no matter if you have the best technology, you still need people to go out to do commissioning. That's fundamental. The off-the-shelf thing that you just send out and it works is not a reality yet. We are bringing the message to end customers that the success of an AGV project highly depends on the involvement of the integrator who normally is the vehicle maker." [BlueBotics]

LINE GUIDED (AGV) NAVIGATION TECHNOLOGY REMAINED THE MARKET LEADING TECHNOLOGY DUE TO ITS SIMPLICITY AND ROI. INCREASED USE OF MIXED APPROACH

LINE GUIDANCE, STILL LEADING THE WAY

- Line guidance (AGV) remained one of the most important navigation technologies in the wider AGV & AMR Robotics sector by virtue of its simplicity and relatively good ROI
- Line guided technologies include magnetic tape, lines painted on floors, induction, etc.
- Component suppliers suggested they continued to spend on R&D and developing new and improved line/floor guidance products, confirming the position in the sector

"We definitely have customers who are doing floor guidance… and we're still developing new versions for this product. So there are no plans for a phase out… that's not even brought up in our development whatsoever. It's so popular that every now and then we have problems stocking it." [Pepperl + Fuchs]

- A few navigation technology vendors supply a range of navigation solutions for customers, including line guided solutions

"We offer many different navigation technologies. In general, customers are increasingly asking for a flexible approach. But we also see a trend that even though you are able to offer a different technology, it's not always what you end up using. Usually there are better ROIs and higher throughput with a more predictable navigation technology. But we do see sales are going up for infrastructure free navigation." [Kollmorgen]

INCREASED USE OF MIXED NAVIGATION TECH

- Interviews suggested that mixing different navigation technologies was becoming more common in order to use the strengths from each technology

"In AMR mode, the accuracy is approximately 2cm. When transitioning to AGV mode, which follows a line, accuracy increases significantly to about 1mm. AGV mode ensures precise stopping accuracy, which is why we integrate both technologies to control our robot." [Lexxpluss]

- There was also interest in combining indoor and outdoor navigation for very specific applications, often for moving between buildings on the same estate

"We have a fully integrated GNSS extension with our software. Now there is a lot of interest in this. I don't believe this will a huge impact in terms of volume, but there are a lot of requests." [BlueBotics]

- Mixing outdoor and indoor was also overlapping with many of the companies targeting applications, such as yard management (truck trailers), etc.

SLAM NAVIGATION TECHNOLOGIES INCLUDE TWO PRIMARY MODULES: LOCALISATION AND NAVIGATION

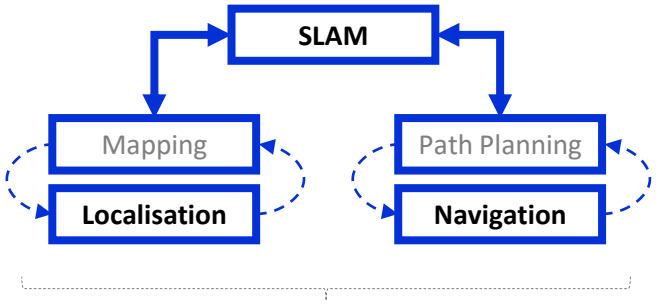
DIFFERENT SLAM TECHNOLOGIES

- SLAM is sometimes referred to as 'Natural Feature Navigation' and currently comes in 3 different 'types of SLAM': 2D, 3D and Visual SLAM
- Differences between SLAM types relate to the sensors being used for localisation
  - **2D SLAM** use 2D Lidars to read a single slice of the environment, also referred to as 'contour navigation'
  - **3D SLAM** use 3D Lidars to read many multiple slices of the environment sometimes also referred to as 'point clouds'
  - **Visual SLAM** use cameras to read in images of the environment and can often add context of what is viewed, i.e. this is a box, that is a pallet, etc.
- Some vehicles, for example forklifts may use a combination of different sensor and SLAM types to execute sensor fusion or for different purposes
- For example, cameras can be used to identify pallets and how they are angled, etc. whereas a 3D Lidar may be used for navigation

LOCALISATION AND NAVIGATION

- SLAM contains two main parts or modules, localisation (where am I) and navigation or path planning (how do I get to my target location)
- The localisation module can also be used for RTLS purposes with any other type of vehicle

SLAM – A SIMPLIFIED OVERVIEW



Source: STIQ Ltd Research & Analysis

"Localization and navigation are the two parts on the vehicle. We are following the 'one fits all software' approach, one software for all vehicles that run on a flat surface where you can use a 2D laser scanner." [Bosch Rexroth]

MAPPING, PATH PLANNING

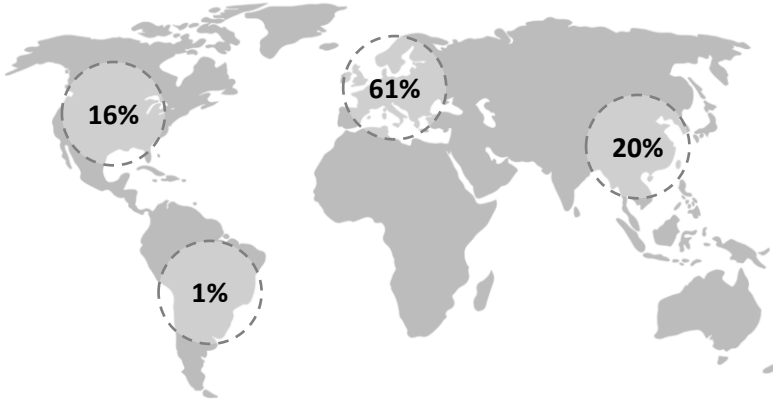
- Mapping typically includes running a vehicle around a facility in manual mode scanning the area to build the SLAM map
- The sensors used to build the map depends on the type of SLAM deployed on vehicles, i.e. 2D, 3D or Visual SLAM
- If using Visual SLAM, this may include various cameras in the facility
- There may be additional work with maps to emphasise fixed infrastructure positions, such as pallet racks, walls, etc.

"When it comes to actual implementation, it appears to us that the challenge… it doesn't matter what type of SLAM machines or natural feature guided vehicles you're deploying, you still have to scan the map. And this process cannot be shortened. Once you have scanned the map, you also have to trim it. You have to perfect it. This process at the moment is still difficult to shorten. So I think still there's going to be quite some time until we get a newer way of implementation. We have developed a couple of more technologies trying to make this easier and more robust. Try to make sure a trained engineer can do it within 4 hours or five hours without coming back and forth. That's something we're trying to work on, but if we're thinking about dramatically eliminating the cost of the implementation. I doubt it will happen in the next year or so." [SEER]

- Mapping also typically include setting corridors of movements outside of which the robots are not allowed to navigate, for example if there are walkways for people, etc.
- Maps also need to take into account if there are automated doors that may need to be integrated, etc.
- Navigation is the robot itself choosing the best path to its target or next staging area keeping within the allowed aisles or areas

SLAM NAVIGATION INCREASINGLY IMPORTANT, BUT FROM LOW BASE. ADOPTION BY KEY USERS COULD ACCELERATE GROWTH. INFLUENCE FROM AUTONOMOUS CARS

NAVIGATION SOFTWARE VENDORS BY CONTINENT



Source: STIQ Research & Analysis. Share of vendors by continent, based on currently identified navigation software vendors

MULTIPLE NAVIGATION SOFTWARE VENDORS

- STIQ tracked nearly 50 vendors of navigation software packages in 2023
- The vast majority of these companies were located in Europe and included some modules based on open source software, such as ROS
- This proliferation of vendors has added to the already high fragmentation in the sector
- However, whilst building the first robot was relatively easy, scaling or ramping up into a production ready vehicle and offering this as a product to external customers was a different challenge

SLAM GROWING AS A SHARE OF NAVIGATION

- SLAM remained a relatively limited share of the overall AGV & AMR sector navigation market in 2023
- However, a number of key users were starting to deploy vehicles using SLAM navigation which could potentially signal and accelerate growth

"If you go back a bit over a year now you saw a major robot user/vendor release a few new robots… and you'll see that none of those use line following. It's all free navigation. And that, in our opinion, we see as the arena where things are going forward. Sales may not reflect it directly, but certainly the activity, the conversations and the future planning for what these companies are doing is 100% geared in that direction. It's just like automotive with electric cars." [Pepperl + Fuchs]

- Interviews also suggested important end customers had upgraded AGVs with SLAM navigation technology

"We just accomplished a project with our autonomous navigation solution for a South Korean conglomerate here in Vietnam. That was a refurb project where we replaced magnetic navigation with our SLAM technology to existing AGVs… they have another facility with 3,000 magnetic tape AGV's. It's a very big project." [Techvico]

- Whilst such replacements occurred, they were unlikely to become a wider trend in the global AGV & AMR Robotics sector

INFLUENCE FROM AUTONOMOUS CARS

- Multiple navigation vendors (and AMR vendors) had employed staff with experience from autonomous cars

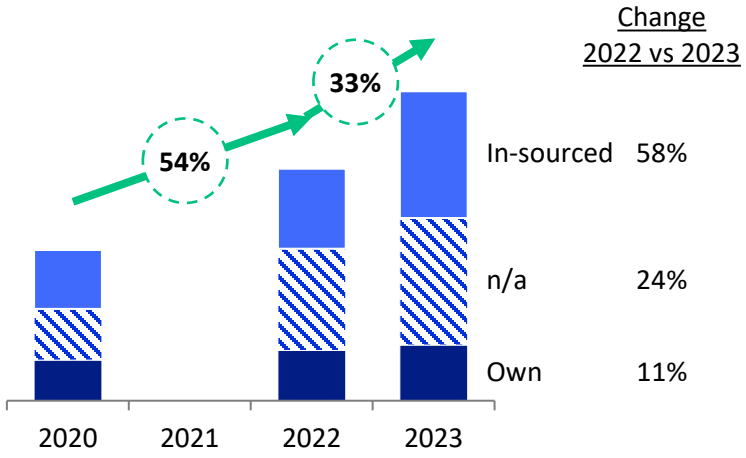
"The founder worked at Bosch previously and was responsible for the autonomous driving applications." [Lexxpluss]

"Our team actually originated from autonomous driving vehicles." [ForwardX]

"We started looking at the potential of applying autonomous driving technologies to industrial applications at the height of the robo taxis after the DARPA challenge. Our system was initially designed to operate outdoor. We deployed vehicles on roads… at container ports. We deployed shuttle buses in a mixed traffic area with passenger vehicles, people running between buildings... All of that was to harden the system when it's going to be deployed into the much, much simpler and slower warehouse and factory environments." [Cyngn]

THE GROWING NUMBER OF SLAM VENDORS AMPLIFIED AGV & AMR SECTOR FRAGMENTATION BY MAKING IT EASIER TO ADD AMRs TO PRODUCT RANGES

NUMBER OF ROBOT VENDORS BY NAVIGATION STACK USED, 2020-2023 (#)



Source: STIQ Research & Analysis. Not tracked in 2021
NOTE: Use chart with caution! Shows the number of AGV & AMR Robotics companies using an outsourced solution to STIQs knowledge (as confirmed by buyer or vendor)

CAUTION RE ABOVE CHART

- STIQs charts are frequently used in various startup fundraising decks
- Note that the chart above indicates # companies that use internal vs external navigation software sources
- This is **NOT the same as the total volume of mobile robots deployed or produced in the market**
- As an example, forklift vendors tend to in-source software as they are not native software companies

INCREASINGLY EASY TO MAKE AGVs & AMRs

- It was never difficult to produce a line guided AGV
- However, SLAM navigation vendors appeared to have been far more aggressive and successful with their sales and marketing activities
- Issues with making any mobile robot (AGV or AMR) involved ramping up and scaling production, reliability, selling to end customers, etc.

"The metric here is if you're starting out as an AMR manufacturer with a new product, ramping up is probably going to take more time than you would expect and I guess that's the experience that many navigation software customers have." [NODE Robotics]

NAVIGATION SOFTWARE BUSINESS MODELS

- Interviews suggested the navigation software business model had to be flexible and follow/fit the way customers were doing business

"We sell localization and navigation as Capex and Opex. It's sometimes a mix because services can be added to the license. And as software is changing quickly, some prefer to have a service contract. so to be able to make use of the updates and improvements in the releases." [Bosch Rexroth]

"Our business model mimics our customers… how they sell their robots… we provide both capex/opex, because we don't want to put our customers in a position where the pricing model is a problem… we also have a modular product. Some customers use our localization SLAM and others use our full navigation stack." [NODE Robotics]

IMPORTANCE OF THE USER INTERFACE

- A growing AGV & AMR market combined with people changing jobs frequently has driven up the importance of an easy to manage user interface
- Increased competition has also accelerated improvements

"We offer a lot simpler system or UI for staff with less experience. I think it's a worldwide phenomenon that people change work quite often. So now you don't have to have worked with our products for 10 years to be able to use it. But experienced users can also handle any kind of situation by using our complete toolbox." [Kollmorgen]

WHILST A GREAT TECHNOLOGY DEVELOPMENT, SLAM TECHNOLOGY PER SE HAD NOT CHANGED AGV & AMR FUNDAMENTALS

THE IMPACT OF SLAM HAS BEEN LIMITED

- SLAM navigation technology has not impacted the way customers have to approach a mobile robotics project when deploying larger or scaling up fleets

"I don't think that SLAM has changed the mobile robotics landscape that much. It depends on the application, but if you go to e-commerce where you can find mostly two types of applications. The 1st is order fulfillment and the 2nd is the sorting. SLAM has changed nothing there. Regarding forklifts moving pallets I'd say no big difference either. Regarding automotive applications like kitting transportation to the assembly line and sequencing, well it has helped a little bit, but most of those applications are still running on magnetic tape. So maybe you're using both technologies, magnetic guidance and SLAM navigation. But yeah, it has not changed our lives that much I would say." [Moving Robots]

POSSIBLY OVERHYPED EXPECTATIONS?

- However, interviews also suggested some of the marketing of these technologies may have derailed a more healthy conversation about customer needs and business cases

"Some customers tend to focus a lot on features and technologies rather than functionalities and performance. One example is SLAM navigation, another example is obstacle avoidance and battery. Customers have been kind of trained to focus on these topics in marketing from technology startups focusing on these features. 10 years ago, it was all the forklift automation guys that built bespoke vehicles. They've been around for 20-30 years. But their design does not typically focus on any of these exotic features. Then you have the startups coming up and they say, we're more productive, we're more efficient because we do SLAM navigation. These marketing campaigns have changed expectations… and the big guys have been struggling with that. But it also derails a healthy conversation on what the customer needs and what a business case can look like." [Movu Robotics]

SLAM POTENTIALLY COMMODITISED

- Some customers also indicated SLAM navigation software would potentially be commoditised and focused instead on creating an ecosystem of applications

"Our take is that navigation will be kind of off the shelf in the future… Our focus will be on innovation in creating an ecosystem between the Navigator, the AMR and a lot of different load carriers." [FlexQube]

2D SLAM IN WIDESPREAD USE, BUT MAY HAVE SPECIFIC LIMITATIONS. VSLAM NASCENT BUT WITH GREAT POTENTIAL

2D SLAM TO BE REPLACED WITH VSLAM?

- 2D SLAM is the most widely used and deployed SLAM navigation technology in the AGV & AMR Robotics sector

"Most AMR robots use 2D Lidar for localization." [RGo Robotics]

- Interviews with VSLAM vendors suggested 2D Lidar SLAM technology had limitations, especially in large open spaces with highly dynamic environments

"There's a global manufacturer in the US with a huge fleet of a vendor's AMRs. They are getting lost because a lot of the customer warehouse environments are very open and dynamic. 2D Lidar will frequently delocalize… sometimes as often as once or twice a day… and get lost. The company contacted us because it has become imperative that they solve this problem." [RGo Robotics]

- Frequent changes and highly dynamic environments could require 3D Lidar or VSLAM technology

"We see a trend that people are unsatisfied with the robustness and efficiency provided by the 2D Lidar. They're very happy with the accuracy provided by the 2D Lidar and this is also why it has been used for a decade… it's mainly about the robustness for 2D Lidar it tends to get lost against scenery change of the environment and cannot restart from any random location. This is happening even more frequently in factories and warehouses, because they are operating in a more agile way. For example, they are frequently changing the layout of their factories or logistic warehouses." [Kudan]

- Furthermore, an issue with 2D SLAM has been how to combine maps where vehicles use different slices of reality to navigate
- For example, a forklift may have a 2D Lidar placed on top of the vehicle and a mouse a 2D Lidar placed 20cm from the ground
- Interviews suggested a 3D approach had solved such issues

"We have solved using the same map on different height levels. So creating one 3D map of the entire layout, then slicing it to those varied height levels as part of our approach to give every device the right viewpoint, while recognizing others as well… and then bringing them back together into one 3D map at the end for the robots to navigate." [idealworks]

VSLAM, A NASCENT TECHNOLOGY

- Interviews suggested VSLAM navigation remained nascent when used for navigation with some important potential hurdles to overcome

"We tried to use VSLAM, but that's very difficult because the customization level of AI is really high. We have to train different models for different plants which is almost impossible, and it takes time. Firstly we need time to train the AI models and we need many videos and pictures of plants… sometimes the factory owner wouldn't allow us to do so. So, it takes time to train and it takes time to convince the clients, so it wasn't really worth it in the end. I think the thing about the industrial sector is not about who comes up with a splendid innovation, it's more about who has the innovation in applications." [Anonymous]

"But clearly I see that the technology side is going far ahead than what the market is being adapted. That's the sad truth." [Starnus]

- However, interviews suggested VSLAM conversations had switched from trying to persuade people about the technology to details about maturity, how to integrate, etc.

"Conversations have changed from persuading customers that VSLAM is the best to, yes, we know vision is the best way. Now tell us about your solution. It's a different conversation and there's an understanding that this is the way forward. Now they want to see if it's mature enough, that it's stable enough, that it's complete enough in terms of the tool sets and things they need in order to integrate, deploy and kind of make sense as part of the fleet management and everything else." [RGo Robotics]

CHIP VENDORS INCREASINGLY INVOLVED

- Chip vendors were actively getting more and more involved in the space especially with more demanding technologies such as 3D and Visual SLAM

"The chip provider has provided us with a special library and we do the integration at a very low software level. This will be much more low power consumption and faster. With this collaboration, we can offload the CPUs which can be allocated for other processing purposes, such as navigation or collision avoidance. End users get more space to run other applications. This is for Visual SLAM. Of course, AGV/AMR is one of the main applications, but this can also run on drones, etc." [Kudan]

VSLAM IS INCREASINGLY ALSO USED AS RTLS (REAL TIME LOCATION SYSTEM) WITH MANUAL INDUSTRIAL VEHICLES

THE VSLAM RTLS USE CASE

- VSLAM technology is also suitable as an RTLS technology and a few vendors had started providing this to AGV & AMR and other vehicle vendors

"The reality is that it's only just recently that the compute required to do Visual SLAM has become cost effective for this market. We together with a couple of other companies are just now beginning to bring VSLAM into the broader AMR market." [RGo Robotics]

"VSLAM is a great technology for RTLS as it can be deployed at scale in minutes and copes well with dynamic environments and it doesn't need mapping or remapping. It can also identify and ignore dynamic objects. Using cameras means we can also capture other things like stock locations, to be used by other systems." [Slamcore]

- VSLAM was sometimes also viewed as a substitute or complement to UWB RTLS technology

"VSLAM is incredibly exciting technology. UWB, Lidar and vision all have edge cases where they struggle. With advanced sensor fusion, a solution can be built that is literally better than the sum of its parts." [Slamcore]

"Everywhere we go there are people saying they can't work with UWB, it's too expensive. It's too hard to maintain. It just doesn't work for us. We need SLAM. We need vision. So there are quite a lot of active opportunities in that RTLS area for even just providing the positioning and the data to a fleet management software." [RGo Robotics]

- There were also particular applications where VSLAM may be a more suitable solution, such as for forklifts

"Forklift positioning is still very tremendous area especially for Visual SLAM. If you want to automate your forklift then maybe you need to use a 3D Lidar. But we also hear from the market VSLAM is used for real time localization systems for the forklifts. Because forklifts are being expected to be working more safely and more efficiently and this is where those positioning systems are contributing." [Kudan]

- Interviews also suggested VSLAM had the potential to enhance many of the existing navigation technologies

"VSLAM can add incredible value in the short to medium term as a complement to existing solutions, perhaps not a replacement for them. VSLAM plus advanced sensor fusion can deliver solutions today that enhance Lidar, UWB or even line or magnetic tape solutions, turning 90% solution into 99.99% solutions." [Slamcore]

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THE AGNOSTIC FLEET MANAGER WAS IN HIGH DEMAND, ESPECIALLY AMONG GERMAN AUTOMOTIVE OEMs IN 2023

AGNOSTIC FLEET MANAGEMENT GROWTH

- VDA5050 was requested in virtually 100% of all automotive AGV & AMR RFQs and appeared to have accelerated important traction for agnostic fleet management solutions
- Multiple interviews suggested there had been a heightened adoption level of agnostic fleet management systems in 2023, leading to something of a platform fight between vendors

"Especially within the German automotive sector, the VDA5050 that's just something you need to do now. But there's an enormous platform fight between all of these fleet management providers. Those selection decisions of course have taken some time, some testing and so on and so forth. And that has also delayed some of those rollouts of the AGV equipment and in many of those bigger companies, the plants can still make independent decisions. Now we are seeing that it is moving, so those decisions have been done and that is starting to release some of the investments in the hardware and installations over the next year or two." [K. Hartwall]

- The size of projects appeared to be growing fast

"We notice that big corporations are engaged in big projects while others are undecided. There's quite a lot going on." [Synaos]

- In fact, multiple AGV projects had been postponed until fleet managers had been decided

"This year we saw a lot of delays on the AGV side with bigger customers, big tier ones in the automotive sector. The cause of the delays were many of them were choosing their universal fleet management supplier. So we did see a lot of delays in many of our bigger customers… they were not actually installing the hardware on the floor because they were selecting who is the universal fleet management supplier and what's the best solution for them long term." [K. Hartwall]

- Drivers for this growth appeared to be VDA5050 and the maturing of various solutions on the market

"We're seeing two developments. Firstly, the mobile robot market is maturing and fleets are getting bigger. Secondly, as robot fleets are growing, they increasingly overlap or interfere with manual vehicles and this has created a need for optimizing and orchestrating entire intralogistics flows." [Synaos]

- However, it should also be noted that the agnostic fleet manager is a relatively young software solution which may also be growing in awareness

"What we see in RFQs and procurement talks and in talks with our customers is that they don't ask about features anymore. They rather ask us, can you provide us global support?" [Synaos]

INTEROPERABILITY STANDARDS, SUCH AS VDA5050 AND MASSROBOTICS APPEARED TO HAVE ENABLED AND ACCELERATED THE AGNOSTIC/UNIVERSAL FLEET MANAGER

INTEROPERABILITY AND FLEET MANAGERS

- AGV & AMR interoperability standards, such as VDA5050 and MassRobotics started life around 2017/2018 and led to an influx of vendors – c.50% of the c.20 FM vendors tracked by STIQ started in 2017-2019
- The agnostic fleet manager (aka 'universal fleet manager') concept was to manage robots from different vendors as a homogenous fleet

VDA5050 STANDARD LEADING THE WAY

- Despite a (currently) limited user base, interoperability appeared to be spreading among both vendors and users
- Of the standards currently available in the market, VDA5050 appeared to be the only one required by some end customers

"Interoperability is a little bit more advanced in Europe than in the US. But the market in the US is changing and picking up as well. Right now, in Europe the VDA5050 standard is more common than the MassRobotics standard is in the US." [Synaos]

- VDA5050 was also spreading as a part of the wider influence of the German automotive sector

"All the European automobile companies which are present in India, they normally ask for VDA5050. Because their standards come from the head office. So they definitely ask for it." [Addverb]

INTEROP STANDARDS BY COUNTRY OF ORIGIN

Source: STIQ Research & Analysis

"One of our US automotive customers explicitly asked for VDA5050. This was significantly influenced by their respective European plants." [Synaos]

AGV & AMR VENDORS HAPPY WITH INTEROP

- AGV & AMR vendors have procrastinated in the past and been largely negative about the impact of VDA5050. However, some now see it as a largely positive impact

"I love the idea of VDA5050 because we would highly profit from such a scenario. I mean, if you have an enterprise level fleet manager, then every single plant is prepared for our system and it will be easy to integrate… with a flick of your fingers. That's why I support the VDA5050 idea as much as I can." [SAFELOG]

COMPETING INTEROP STANDARDS

- Competing standards include MassRobotics in the US and a new initiative in Japan

"We are working with some automotive customers actually to build up the new standards for this new equipment. Because none of the companies have the standard for AMRs. So they don't know what's the good AMR with enough fit as a part of their production process." [Lexxpluss]

- However, to STIQs knowledge, none of these standards were currently required by any particular industry sector

PLENTY OF NON-COMPLIANT VEHICLES

- Most of the currently deployed AGVs & AMRs in the marketplace were non-VDA5050 compliant vehicles adding a level of integration for adoptees

"we also do VDA5050 and non-VDA5050. because some customers may have 20-30-40 or more AGVs which don't have VDA5050 and they don't want to throw them away. Then we offer to develop a specific adapter for using these non-compliant AGVs in our fleet manager." [MHP]

VDA5050, DEVELOPED BY THE AUTOMOTIVE SECTOR BUT ALSO SLOWLY GAINING GROUND OUTSIDE OF AUTOMOTIVE. POTENTIAL FOR CONFUSION

FEW NON-AUTOMOTIVE USERS OF VDA5050

- Few customers outside of the Automotive sector request VDA5050

"Not a lot of non-automotive industries ask for VDA5050. I have not seen it." [Addverb]

"Today, it's still quite rare for us to see VDA5050 requests. But I think requests will come more and more. I'm not sure how often it will be 100% integrated with these fleet managers because everybody has their own way of integrating… and VDA5050 is not covering this requirement." [Linde MH]

- Non-automotive customers also appear to have decided to use fleet managers with the VDA5050 standard

"We have a customer who operates in the food sector. They're now using this in one of their major plants. This is something that we see in the market as well. We have to be applicable and successful at one plant. Often customers then make a global decision. There are only a few companies that decide right away from a central level without approving you in a single plant first." [Synaos]

"We have many implementations over the past years in the food area. This is obviously coming out of the automotive area... But we also have some implementations in pharmacy and aviation." [Movizon]

VERY FEW MIXED FLEETS (CURRENTLY)

- Interviews suggested there were very few multi-vendor environments around, especially where vehicles interacted with each other

"The use case where you have to integrate 17 different AMRs or AGVs doesn't exist yet. It might be a test case somewhere, but this is not a problem that clients are facing today. Yes, integration of many vehicles might be the next logical step to bridge the time until you see that necessity in the market." [idealworks]

"Right now we see zero. Right now zero" [Versabox]

"We're finding that the interop stuff is still really early, at least in the US." [Vecna Robotics]

VDA5050 CONFUSING CUSTOMERS?

- Some interviews suggested interoperability standards may add to the current level of confusion, especially for new users of mobile robots

"VDA5050 is also leaving customers a little bit puzzled. We lately see it as a requirement in nearly every tender. However, it seems that many of them just add this requirement to be 'future proof', not because they see an instant benefit. They just run one type of robot but don't want to spoil the chance to add robots from other vendors to their fleet in future projects. And that's what is pushing VDA5050 additionally." [Anonymous]

VDA5050 v 2.0.0 OUTLINE

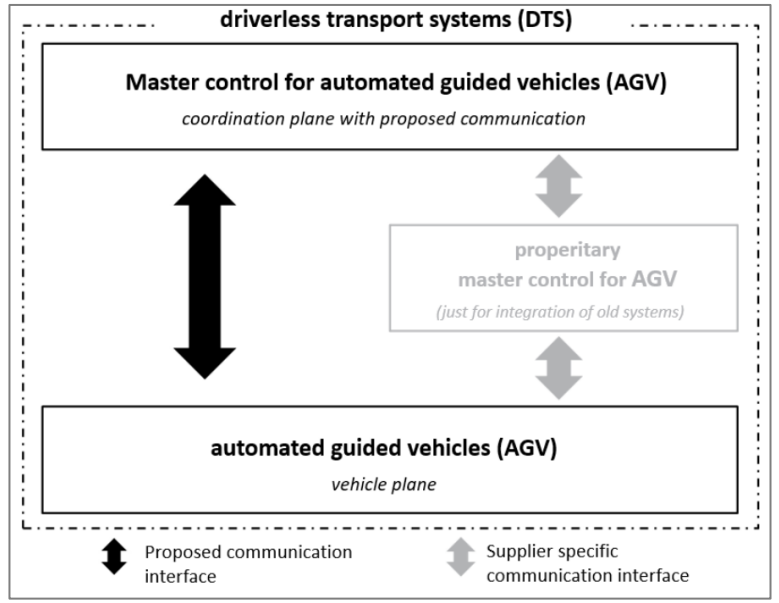

Image Source: VDA (link - links directly to pdf download of Recommendation for VDA5050 v2.0.0 from 2022)

THE AGNOSTIC/UNIVERSAL FLEET MANAGER APPEARED TO BE UNDERGOING AN EVOLUTION TO AN INTRALOGISTICS OPERATING SYSTEM

FROM UNIVERSAL VEHICLE CONTROL TO INTRALOGISTICS OPERATING SYSTEM

Function	Order Management	Order Management + Traffic Management	Order Management + Traffic Management
Operation	Fleet Manager	Agnostic Fleet Manager VDA5050, MassRobotics	Intralogistics Operation System RTLS
Vehicle/Fleet Type			
	Homogenous Robot Fleet	Heterogenous Robot Fleet	Hybrid Fleet (Robot + Manual)
Description	**Vendor's Own Fleet Manager** • In a homogenous robot fleet, vendors will typically add their own fleet manager • A fleet manager is not always required for small fleets <5 vehicles	**Agnostic/Universal Fleet Manager** • In the ideal heterogenous robot fleets a 3rd party agnostic fleet manager could be deployed to transmit orders to each vehicle from different vendors • Whilst not necessary, standards such as VDA5050 makes the communication protocols and interoperability easier	**Intralogistics Operating System** • In a mixed/ hybrid environment with robots and manual vehicles, the Intralogistics Operating System may be able to control vehicles to ensure a smooth flow of traffic to the benefit of output rather than individual systems • SLAM localisation technology can also be used for RTLS

Key: Catalyst

THE AGNOSTIC FLEET MANAGER SALES PITCH

- STIQ interviews have continued to suggest the agnostic fleet manager was a tough sell on its own
- This appeared to have spurred innovation in the software segment and vendors have added novel approaches to fleet management

"Selling a fleet management software can be challenging as most AMR vendors have their own solution. We found a niche. We not only do fleet management, but also orchestrate the entire flow of the facility. We connect to MES systems and move them into our solution." [Arendai]

"We're expanding in terms of product depth regarding our key solution mobile robot fleet management. In addition, we're onboarding manually guided vehicles like industrial trucks, forklifts, tugger trains into our solution. So, we're investing in making our solution broader and also add features in areas we're already active in: mobile robots and VDA5050." [Synaos]

- Such innovations have also tilted software vendors into a wider intralogistics orchestration role with potentially a more consultative approach

"There are huge customers who only decide on a mobile robot fleet management system when we can integrate their forklifts, tugger trains and industrial trucks as well. That's the only viable way. We want an overall optimization of their entire intralogistics." [Synaos]

Source: STIQ Ltd Research & Analysis. Pictures: vendor's own and Freepic

RISE OF THE FLEET MANAGEMENT CONSULTANCY? NEW FM FUNCTIONALITIES EMERGING. INCREASED COMMODITISATION OF ROBOTS, AN ADDITIONAL DRIVER

NEW FUNCTIONALITY EMERGING?

- Additional functionalities appeared to be emerging, especially as the segment remained relatively young

"Right now we can orchestrate orders and track all kinds of vehicles using RTLS. Routing will be added in 2024 to complete this higher level traffic management solution." [Synaos]

"Our engine can send a robot to a working cell to pick up a product ahead of time, as we know when the product will be ready. We focus on the optimization of workflows for robots." [Arendai]

"At the moment we call it a fleet manager, but we are thinking about redesigning the marketing because we are doing a lot more… steering conveyors, orchestrating lifts… interface to sensors, different ERP, WMS, it's a lot more than only giving transport orders to AGVs." [MHP]

- Some interviews also suggested vendors were developing other novel approaches to the fleet manager

"We also have a Manufacturing WMS or MWMS. There's a slight difference between our WMS with something from Blue Yonder. Ours is a combination of WMS plus a fleet manager." [SEER]

- However, keeping production and logistics systems separated was good practice

"The system landscape between classic production system and logistics systems are still separated for very good reasons. Because you want to have less risk, less interference when either system go down." [idealworks]

THE RISE OF THE FM CONSULTANCY

- Additional functionality also meant some of these vendors increasingly appeared as consulting firms

"We also have separate and different customers for RTLS right now. Because you can put this on a manual forklift and do some heatmap analysis if you use it as a standalone solution." [Synaos]

AGV & AMR HARDWARE COMMODITISED?

- Interviews suggested AGVs & AMRs may be commoditised and that this had partially also pushed the focus to developing software such as fleet managers

"Vietnamese robotics makers prefer not to produce their own AMR's. Instead, they OEM from China. It doesn't really make sense to develop their own AMRs. Instead, I see the trend going towards developing the software, the fleet manager that can interface with these Chinese OEM AMRs and then just do project integrations." [Techvico]

"In the beginning, we considered building our own AMR. We found that there were 200 vendors, the market was already saturated. Hardware is also difficult due to its cost and resource-intensive nature. Software, however is something that we know very well, and we saw a niche." [Arendai]

"There will be more AGV & AMR manufacturers every year. The most important thing is the fleet manager. So there will be a movement from AGV fleet management to the universal fleet manager." [MHP]

INTERNAL FMS DEVELOPMENTS

- Interviews also suggested at least one multi-$bn revenue end customer had opted to develop their own FMS, based on VDA5050

"We have customers that are doing their own software based on VDA5050." [SAFELOG]

"One big retail company asked us if we were VDA5050 compliant since they have their own fleet management system." [Addverb]

- STIQs interpretation was the customer most likely had a large internal IT department with a strategic board level decision to vertically integrate its approach to warehouse automation and material handling
- One option could have been to produce their own robots internally in a similar fashion to Amazon
- However, this company most likely did not want to start producing robots internally which would have brought its own separate challenges

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MORE THAN 50 M&A TRANSACTIONS SINCE 2012 WITH NEARLY 90% OF ALL DEALS BETWEEN 2017-2023

AGV & AMR Robotics, Nov 2023
Published by WWW.STIQ.LTD
Important: include source when copying from this free report

AGV & AMR SECTOR TRANSACTIONS, 2012-2023 (NOT EXHAUSTIVE)

2012
- Amazon acquire Kiva Systems

2013
- KION Group IPO IPO
- Oceaneering acquire Frog

2014
- KUKA acquire Swisslog

2015
- Körber acquire Consoveyo
- KION acquire Egemin
- Omron acquire Adept

2016
- Siti B&T IPO IPO
- Krones Group acquire majority stake in System Logistics

2017
- Balyo IPO IPO
- FlexQube IPO IPO
- Kudan IPO IPO
- Matthews acquire Guidance Automation
- ST Engineering acquire Aethon
- Asseco Group acquire majority stake in CEIT
- Altra acquire Kollmorgen
- Miele acquire majority stake in Yujin Robot

2018
- Muratec acquire AGVE Group
- Scott Automation acquire Transbotics
- Teradyne acquire MIR
- STÄUBLI acquire 70% of WFT
- SSI Schaefer acquire stake in DS Automotion
- K Hartwall acquire majority stake in A&A

2019
- Keensight acquire stake in ASTI
- Teradyne acquire AutoGuide
- ASTI acquire InSystem
- Amazon acquire Canvas Technology

2020
- Porsche acquire Serva TS
- Jungheinrich invest in Magazino
- Seegrid acquire Box Robotics
- H14 acquire stake in E80 Group
- KION acquire stake in Quicktron
- Kudan acquire stake in Artisense

2021
- Verizon acquire IncubedIT
- Locus acquire Waypoint
- Zebra acquire Fetch Robotics
- ABB acquire ASTI
- Jungheinrich acquire Arculus
- JASCI acquire Nextshift
- Elektroautomation acquire EA Mobile Robots
- Cyngn IPO IPO

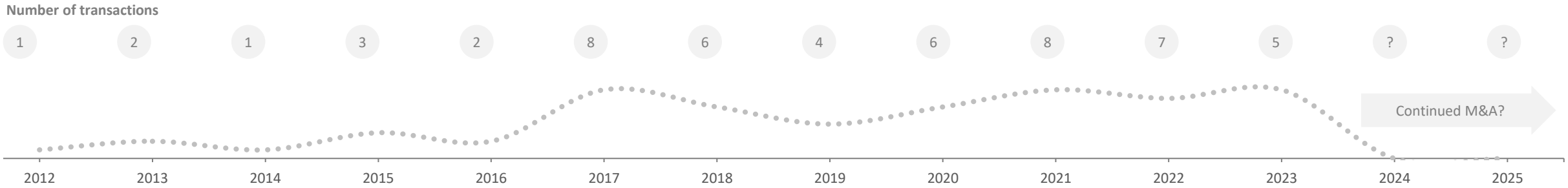
2022
- Phantom Auto acquire Voysys
- Latour acquire MAXAGV
- Reliance Retail acquire majority stake in Addverb
- STOW acquire majority stake in iFollow
- Zapi acquire BlueBotics
- Teradyne merge MIR and AutoGuide
- K Hartwall acquire remaining stake in A&A

2023
- Barcoding acquire Fred Automation
- Balyo taken private by SoftBank
- Regal Rexnord acquire Altra
- Jungheinrich acquire Magazino
- Rockwell acquire Clearpath/Otto Motors
- Agile Robots acquire idealworks + BAR Robotics
- Continental acquire Kinexon

2024

2025

Key: IPO IPO, public listing



Source: STIQ Ltd research & analysis
Note: Mitsubishi (now Mitsubishi Logisnext) acquired Rocla in 2008. Amazon's acquisitions of Kiva Systems in 2012 and Canvas Technology in 2019, and companies such as 6 River Systems are covered in STIQ's G2P Solutions reports alongside KION's investment in Quicktron, etc. (download STIQs G2P reports here for free)

SUSTAINED M&A ACTIVITY FROM 2017 LIKELY TO CONTINUE AND POSSIBLY ACCELERATE. MULTIPLE "ACQUIHIRES" LIKELY IN THE SHORT TERM

TYPES OF ACQUISITIONS (NOT EXHAUSTIVE)

DESCRIPTION
Bolt-on Acquisition • Acquirer is looking to expand or diversify its product ranges with additional products that may add value in a total solution • For example, a Cobot manufacturer may acquire a mobile robot manufacturer
Consolidation Acquisition • Acquirer is looking to consolidate product or market position by strengthening its offer • For example, an AGV vendor may acquire a SLAM navigation technology vendor to add AMRs to their ranges, or could acquire a vendor in another country to establish a presence

Source: STIQ Ltd Research & Analysis

SUSTAINED M&A ACTIVITY SINCE 2017

- There has been relatively high levels of M&A activity in the AGV & AMR Robotics sector since about 2017
- This continued at a relatively similar level throughout the pandemic between 2020-2022
- STIQs view is this will continue and may also experience blips of heightened activity, especially as VC money flows remain restricted
- This could lead to a rise in "acquihires" where companies acquire startups primarily to gain access to their human resources rather than technology, products or IP

AGV & AMR SECTOR CONSOLIDATION

- Many STIQ conversations with AGV & AMR Robotics stakeholders have featured views of varying degrees that the AGV & AMR sector is ripe for consolidation
- However, STIQ has seen little evidence of widespread consolidation in the sense of two vendors with similar product/s consolidating product range and or market position
- Most (75%) acquisitions from 2012 to now by product companies have been executed to diversify product ranges, i.e. an industrial company may acquire a mobile robot company to widen product ranges it can offer to customers
- Only c.25% of acquisitions from 2012 to now, by product companies, were executed seemingly to strengthen the position of the company in its original sector
- Consolidation acquisitions in the AGV & AMR Robotics sector were more likely to include a physical hardware product company and a software company due to low barriers to entry in hardware

TAKE PRIVATE OF LISTED COMPANIES

- In 2023, SoftBank offered Balyo's shareholders to purchase the entire company in a "take private" action
- This was the second company SoftBank has taken private in the material handling sector since 2022 (Berkshire Grey, US – not covered in this report)
- SoftBank had managed to acquire c.70% of the equity of Balyo in early Nov 2023

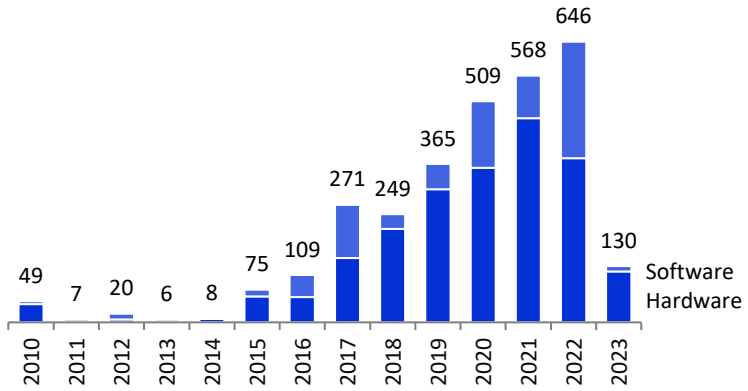
BALYO SHARE PRICE, 2018-2023 (€)

Source: Google (source)

- Reasons for taking private often include an underperforming share price combined with a view there is value in the company assets, not appreciated by public markets
- Privatised companies frequently return to public markets after a few years under PE ownership

HIGH M&A ACTIVITY LIKELY TO REMAIN WITH AN INCREASED LEVEL OF STRESS IN THE SECTOR. NEW FUNDING HAS DRIED UP

ANNUAL FUNDING IN THE AGV & AMR ROBOTICS SECTOR, 2010-2023 ($M)



Source: STIQ Ltd Research & Analysis, Crunchbase

$3BN INVESTED SINCE 2010

- STIQs continued coverage highlighted that just over $3bn has been invested in the AGV & AMR sector since 2010 with nearly 60% of all funding during Covid
- Investments in 2023 appeared to have dried up

STRUGGLING VENDORS BOOSTING M&A

- Interviews for this report suggested an elevated stress level for companies with a few businesses struggling
- This was likely to boost short to medium term M&A activity

"I think we are going to see further consolidation in the AMR sector. So whoever is still for sale might either go bust or getting sold." [Anonymous]

"I think, in China the small companies for robotics will finally disappear. The market is very competitive and every customer is searching for lower prices." [Hangcha]

"There is a lot of fragmentation. That's one of the few things that I'm happy about the crisis, because this should perhaps clean up a bit all this mess." [Anonymous]

- Likely acquirers include stronger vendors that may want to exploit customer exposure, technology or employees
- However, there was also potential for corporate acquirers in the space, especially following on acquisitions by Teradyne, Rockwell, Zebra, ABB, etc.
- PE firms have rarely featured in the sector (due to a lack of multiples) but some of these may have been buoyed by Rockwell's $600m acquisition of Otto Motors and there is potential for more PE acquisitions

HIGH LEVEL OF M&A SINCE 2017

- There has been an average of 6.2 M&A transactions per year in the AGV & AMR Robotics sector from 2017
- AutoGuide and MIR was merged by the owner Teradyne

"The reason for the merger is that we want to strengthen the overall offering that we have towards the market, so make the broadest product portfolio on one software platform." [MIR]

- Jungheinrich acquired Arculus (and Magazino), apparently to support its 2025 strategy

"After consolidating our acquisitions, we are quite well prepared to have a bigger impact in the market again next year." [Jungheinrich]

- K.Hartwall acquired A&A to gain technology and an important customer

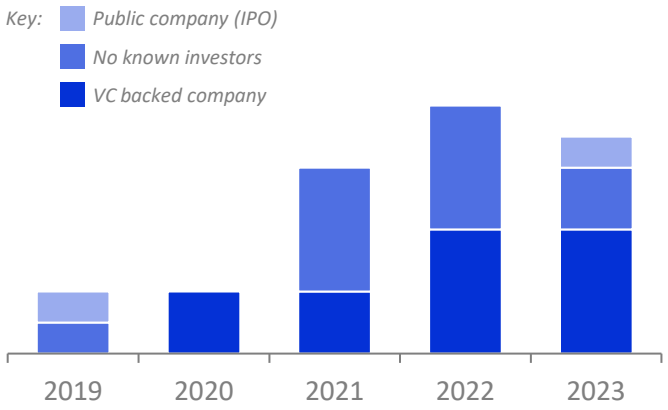
"A&A had a strong technology and was working on sophisticated projects within automotive, but as the customer was concerned about the size of the company, we agreed to step in as majority owner. This was also a very good fit to our strategy to expand our automation offering." [K. Hartwall]

M&A CAN BE A RISKY STRATEGY

- Confidential conversations with various stakeholders highlighted there were quite a few AGV & AMR sector transactions where the combined value remained elusive
- If you want to discuss M&A, STIQs analysts have a background in M&A Due Diligence research – contact us for a conversation

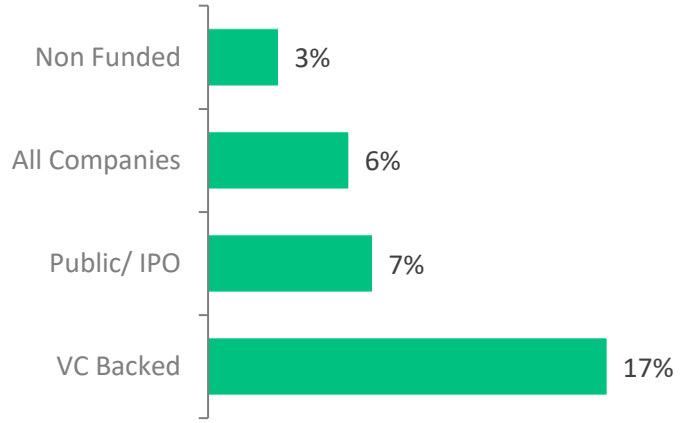
INCREASING NUMBER OF CEO CHANGES IN THE AGV & AMR SECTOR DURING THE PANDEMIC. VC BACKED COMPANIES MORE LIKELY TO SWAP CEOs

NEW VENDOR CEOs, BY YEAR STARTED, 2020-2023, (#)



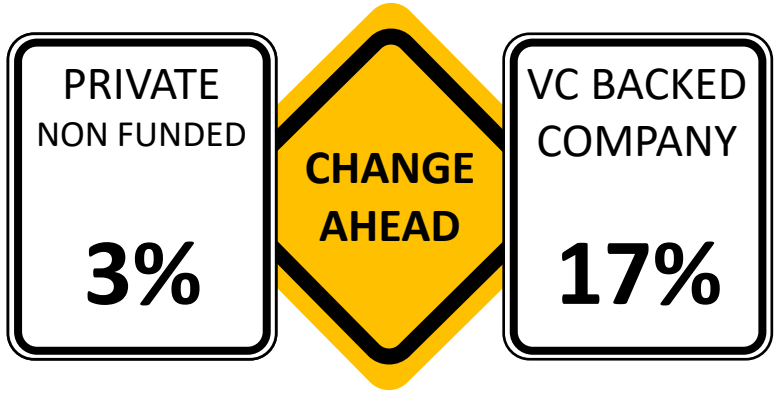
Source: STIQ Ltd Research & Analysis. 2023, year to Oct. Excludes divested, acquired companies

SHARE OF CEOs REPLACED IN THE LAST 5 YEARS



Source: STIQ Ltd Research & Analysis. 2023, year to Oct.
Note "All Companies" = all the companies STIQ track in the sector (c.500)

NEW CEO IN THE LAST 5 YEARS (%)



Source: STIQ Ltd Research & Analysis. 2019 - Oct 2023, CEO used in wide context, i.e. the ultimate business decision maker including Managing Director, etc.

THE AGV & AMR ROBOTICS CEO TRACKER

- There can be multiple reasons why CEOs are replaced, however, these can often be divided into "forced" or "unforced" reasons
- Forced reasons tend to be related to performance issues where a board or other stakeholders push through a change to improve performance
- Unforced reasons could include ill health, long term replacement planning, retirement, etc.
- Whether forced or not, reasons for changing the CEO can often be opaque, but typically means something needs fixing in the company

OWNERSHIP, A KEY DYNAMIC

- A key dynamic to CEO changes was business ownership
- Non-VC backed or Public companies typically have mainly founder owners and are less prone to change
- Companies with equity investors were far more likely to change leadership compared to companies without investors
- Among the c.450 AGV & AMR Robotics vendors tracked by STIQ, 28 were public and 70 were VC backed
- The chance for being replaced in the last 5 years for a CEO of a public company was c.7% compared to c.17% for a CEO at a VC backed company
- Across all the companies STIQ tracks in the sector, c.6% had experienced a change of leadership in the last 5 years compared to 3% at private companies with no known external funding

INCREASING # CHANGES AT THE TOP?

- Whilst STIQ only tracked very recent developments, there appeared to have been an increase in the number of CEO changes since the onset of the pandemic in 2020
- This could be related to performance issues, i.e. "if competitors or similar companies are performing well, why are we not?"
- STIQs view is that the pace of CEO changes will develop in parallel to M&A activity

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AGV & AMR VENDOR PROFILES: A-A

WANT TO FEATURE IN THIS DIRECTORY?

STIQ tracks c.500 AGV & AMR vendors globally and profile c.100 vendors in this **#public** report. To feature:

1) Have a great product, and/or
2) Agree to an interview, and/or
3) Advertise, and/or
4) Contact tom@styleintelligence.com

ABB Mobile Robots

ES | 1982 | Global (parent co)
- AGV/AMR vendor
- ABB acquired ASTI mobile Robots in 2021 for $190m

Accerion

NL | 2015 | -
- Localization vendor

Addverb

IN | 2016 | US,NL,SG,AU
- System integrator with AGV/AMR range

AgileX

CN | 2016 | -
- AGV/AMR vendor

Agilox

AT | 2017 | -
- AGV/AMR vendor

Aitech

SG | 2013 | -
- AGV/AMR vendor

Company Profiles: How to read?

US(HQ) **| 2017**(founded) **| JP**(other offices)

= links to:
- W = company website
- in = LinkedIn profile
- Cb = Crunchbase profile
- > = YouTube profile
- = interviewed for this report

Aiten Popifyindustrial

CN | 2017 | -
- AGV/AMR vendor

Alstef Group

FR | 1961 | Global
- System integrator with AGV/AMR range
- Merged with BA Systemes in 2018

Anantak Robotics

US | 2014 | -
- Navigation software vendor

Alias Robotics

ES | 2018 | -
- Cyber security solution vendor

Anronaut

CH | 2002 | -
- AGV/AMR vendor

Arendai

US | 2018 | -
- Software vendor

Automni

BR | 2014 | -
- AGV/AMR vendor

AGV & AMR VENDOR PROFILES: B-D

AGV & AMR Robotics, Nov 2023
Published by WWW.STIQ.LTD

Balyo

FR | 2005 | US
- AGV/AMR vendor
- IPO in 2017, taken private by SoftBank in 2023

BAR Automation

DE | 1972 | -
- AGV/AMR vendor
- Acquired by Agile Robots in 2023

BlueBotics

CH | 2001 | Global (Parent)
- Navigation software vendor
- Acquired by Zapi Group in 2022

Bosch Rexroth

DE | 1795 | Global
- Navigation software vendor
- Subsidiary of the Bosch Group

Brisa

BR | 2018 | -
- AGV/AMR vendor

Casun

CN | 2007 | -
- AGV/AMR vendor

CEIT

SK | 1998 | -
- AGV/AMR vendor
- Acquired by Asseco Group in 2017

Company Profiles: How to read?

US(HQ) **| 2017**(founded) **| JP**(other offices)

= links to:
- W = company website
- in = LinkedIn profile
- Cb = Crunchbase profile
- > = YouTube profile
- = interviewed for this report

Christensen Strategy Group

US | 2022 | -
- Consulting firm

Continental

DE | 1871 | Global
- AGV/AMR vendor (BU within Continental Automotive business unit)

Cyngn

US | 2013 | -
- Navigation software vendor

Daifuku

JP | 1937 | Global
- System integrator with AGV/AMR range
- IPO in 2017

Dematic

US | 1819 | Global
- System integrator with AGV/AMR range
- Acquired by KION Group in 2016 for $2.1bn

DS Automotion

AT | 1984 | -
- AGV/AMR vendor
- Acquired by SSI Schaefer in 2018 (majority stake)

DTA

ES | 1974 | -
- AGV/AMR vendor

AGV & AMR VENDOR PROFILES: E-I

AGV & AMR Robotics, Nov 2023
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E80 Group

IT | 1980 | Global

- System integrator with AGV/AMR range

EK Robotics

DE | 1980 | UK,IT,CZ

- AGV/AMR vendor

Ez-Wheel

FR | 2009 | -

- Component supplier
- Acquired (majority stake) by IDEC in 2023

Filics

DE | 2019 | -

- AGV/AMR vendor

FlexQube

SE | 2010 | US

- AGV/AMR vendor
- IPO in 2017

ForwardX

CN | 2016 | US,JP,KR,SG

- AGV/AMR vendor

Geek+

CN| 2015 | US,JP,DE,UK,SG,

- AGV/AMR vendor

Company Profiles: How to read?

US(HQ) **| 2017**(founded) **| JP**(other offices)

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Gideon

HR | 2017 | -

- AGV/AMR vendor

GIM Robotics

FI | 2014 | -

- Navigation software vendor

Grenzebach

DE | 1960 | Global

- AGV/AMR vendor

Hangcha

CN | 1956 | Global

- AGV/AMR vendor

HMS Networks

SE | 1988 | Global

- Component supplier

idealworks

DE | 2020 | -

- Fleet management software vendor with AGV/AMR vehicle
- Acquired (majority stake) by Agile Robotics AG in 2023

IncubedIT

AT | 2011 | -

- Navigation software vendor
- Acquired by Verizon in 2021

AGV & AMR VENDOR PROFILES: J-L

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JBT Corp

US | 1894 | Global
- AGV/AMR vendor

Jungheinrich

DE | 1953 | Global
- AGV/AMR vendor

Karter

NL | 2021 | -
- AGV/AMR vendor
- Part of Weighpack group

K. Hartwall

FI | 1932 | Global
- AGV/AMR vendor

Kivnon

ES | 2007 | -
- AGV/AMR vendor

KOLLMORGEN

SE | 1972 | SE, US, CN, IT, DE, KR

NDC Solutions by Kollmorgen is an industry leading platform utilized by top vehicle builders to create driverless logistics automation solutions. The platform consists of both software to manage fleets and route vehicles efficiently, and hardware for navigation and control. With Kollmorgen you have the power to automate virtually any type of vehicle, in any industry, worldwide.

Predictable • Flexible • Dynamic

kollmorgen.com/agv

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Kontro Hertz

KR | 2018 | -
- System integrator

Körber Business Area Supply Chain

DE | 1946 | Global
- System integrator

Kudan

JP | 2011 | UK,DE,US
- Localization vendor
- IPO in 2018

LexxPluss

JP | 2020 | -
- AGV/AMR vendor

Linde Material Handling

DE | 1904 | Global
- AGV/AMR vendor
- Merged into the KION Group in 2006

AGV & AMR VENDOR PROFILES: L-M

AGV & AMR Robotics, Nov 2023
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Lowpad

NL | 2017 | -
- AGV/AMR vendor
- Part of Eurogroep

MAG (Mobile Automation Group)

US | 1987 | (Non-Profit Association)
- We are an independent authority comprised of over 40 OEMs, component manufacturers, integrators, and consultants.
- Through blogs, podcasts, seminars, videos, and other thought leadership avenues, we inform practitioners, end-users, and suppliers on market trends, technology developments, and applications.
- Provide education and scholarships to students and young professionals to bolster the industry.

MAXAGV

SE | 2004 | -
- AGV/AMR vendor
- Acquired by Latour in 2022

MHP

DE | 2013 | Global
- Fleet management software vendor
- Part of MHP consulting group, parent Porsche

MIR

DK | 2013 | Global
- AGV/AMR vendor
- Acquired by Teradyne. Merged with Autoguide Mobile Robots in 2022

Mitsubishi Logisnext

FI | 1942 | Global
- AGV/AMR vendor
- [Rocla] Acquired by Mitsubishi in 2008

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MOBOTIC GmbH

DE | 2019 I -

MOBOTIC offers all 3 AGV/AMR drive configurations; **Differential Drive, Omni with Steered-Traction units, Omni with MecanumWheels.**
With extensive experience in Mobile Robotics, we provide you with the **best drive system options for your AGV or AMR** and accompany your project from the concept, through development and testing into the serial production.

MOBODRIVE ST - STEERED TRACTION UNITS
Our MoboDrive ST is a well-engineered assembly of a steering actuator with endless rotation, high-torque traction unit, safe redundant encoder systems and robust motor control electronics.

info@mobotic.de +49 160 400 56 87 https://www.mobotic.de

Moontech Industrial

ES | 2013 | -
- System Integrator

Mov.ai

PT | 2016 | IL
- Navigation software vendor

Moving Robots

ES | 2023 | -
- Mobile robotics consultancy

AGV & AMR VENDOR PROFILES: M-O

Movizon

DE | 2018 | -

- Fleet Management software vendor

Movu Robotics

BE | 2022 | US

- AGV/AMR vendor
- Stow Robotics acquired iFollow in 2022. Renamed to Movu Robotics in 2023

Muratec

JP | 1935 | Global

- System integrator with AGV/AMR range

NODE Robotics

DE | 2020 | -

NODE Robotics offers user-centric software solutions that simplify the use of mobile robots (AGVs/AMRs).

NODE.OS modular products include:
Live SLAM localization which updates the initial map during operation, ensuring robust localization even in highly dynamic environments.
Adjustable autonomous navigation enabling mobile robots to navigate safely and efficiently, even in complex environments.
Fleet management & coordination services to efficiently coordinate collaboration between robots.

Benefits:
Proven reliability: Over 700+ mobile robots effectively utilized by NODE Robotics in industrial and warehouse settings.
Ease of use: Significantly reduce on-site integration time, allowing end users to make changes independently.
Modular: Offers flexibility to merge in-house systems with various modules, facilitating unique solution creation atop our products.
Hardware agnostic: Select the hardware that's ideal for your application.

Try out the capabilities of NODE.OS with our low-cost Experience Package. You can implement the solution on your own mobile robots (AGVs/AMRs) within a day and start testing the core features.

Contact us for more information.

Scan/click for contact

NAiSE

DE | 2017 | -

- Fleet Management software vendor

Navitec Systems

FI | 1998 | US

- Navigation software vendor

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Nipper AGV

NL | 2013 | -

- AGV/AMR vendor
- Part of F3 Design

Oceaneering Mobile Robots

US | 1984 | Global

- AGV/AMR vendor
- Oceaneering acquired Frog AGV Systems in 2013. Renamed to Oceaneering Mobile Robots

OCME

IT | 1954 | US,MX,SA,CN,TH

- AGV/AMR vendor

Okamura

JP | 2013 | -

- System integrator with AGV/AMR range

Omron

JP | 1933 | Global

- AGV/AMR vendor
- Omron acquired Adept in 2015

AGV & AMR VENDOR PROFILES: O-R

Oppent

IT | 1960 | ES,TR,DE,FR,AE
- AGV/AMR vendor

Otto Motors

CA | 2013 | -
- AGV/AMR vendor
- Acquired by Rockwell Automation in 2023

Outrider

US | 2017 | -
- AGV/AMR vendor

Pepperl + Fuchs

DE | 1945 | Global
- Component supplier

MAG Mobile Automation Group

Proxima Robotics

IT | 2018 | -
- Navigation software vendor

Phantom Auto

US | 2017 | -
- Remote control software vendor

Rapyuta Robotics

JP | 2014 | -
- AGV/AMR vendor

Company Profiles: How to read?

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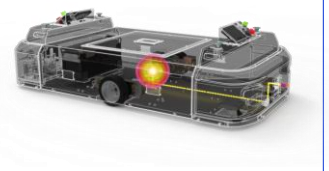
RGo Robotics

IL | 2018 | US

- RGo Robotics has pioneered a 3D vision-based localization and perception technology that empowers mobile robots to understand complex surroundings and operate autonomously — both indoor and outdoor.
- **Visual SLAM & Perception**: RGo's Perception Engine enables AGVs and AMRs to see and understand complex surroundings and operate autonomously just like humans.; facilitating seamless navigation in warehouses and manufacturing facilities. Perception Engine is a software solution that operates on ultra-low-cost, low-power hardware.



- RGo's business model is to partner with robotics manufacturers who share our vision of a future where automation is unfettered but focused on real-world solutions.

Robot Center

UK | 2010 | -
- System integrator

Robotize

DK | 2016 | -
- AGV/AMR vendor

Romb Technologies

HR | 2018 | -
- Navigation software vendor

AGV & AMR VENDOR PROFILES: S-S

SAFELOG GmbH

DE| 1996| US, HU

- Leading software-based provider for intelligent and innovative logistics systems based on mobile robots.
- Portfolio includes patented hardware and software solutions for intuitively operable picking systems as well as several models of mobile transport robots.
- The core of the system is the highly flexible agent based control software with swarm intelligence that does not require a higher level control system. Cost-effective projects can be implemented with several hundred, or just a few SAFELOG mobile robots.

Scott Automation

AU | 1982 | Global

- AGV/AMR vendor
- [Transbotics] Acquired by Scott Automation in 2018 for c.$5m

Company Profiles: How to read?

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Slamcore Limited

UK | 2016 | US

Slamcore is a vision-based SLAM software company that provides localization and mapping solutions combining **state-of-the-art visual-SLAM** technology, sensor fusion and advanced AI, powered via the Slamcore SDK**.**

Slamcore solutions seamlessly integrate in new and existing products, enabling redundancy, increasing robustness and precision, by providing **real-time positioning** for manually and autonomously controlled vehicles.

Advanced AI enables our customers to improve operational safety and efficiency by **detecting and tracking** people, other vehicles and assets in the surroundings.

At **Slamcore** we are continuously improving our technology and products - Get in touch with us to find out more.

Seegrid

US | 2003 | -

- AGV/AMR vendor

SEER

CN | 2015 | -

- Component supplier

Sevensense Robotics

CH | 2018 | -

- Navigation software vendor

SICK

DE | 1946 | Global

- Component supplier

Slip Robotics

US | 2020 | -

- AGV/AMR vendor

AGV & AMR VENDOR PROFILES: S-V

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Standard Robots

CN | 2015 | -
- AGV/AMR vendor

Starnus

NL | 2021 | -
- AGV/AMR vendor

Synapticon

DE | 2012 | -
- Component supplier

Company Name

DE | 2018 | -

SYNAOS presents the world's first comprehensive intralogistics management platform. It offers key solutions for mobile robot fleet management, warehouse execution, and real-time localization. Its Intralogistics Management Platform (IMP) simplifies complex intralogistics operations by integrating transport units, human operators, and automated vehicles into a single, efficient system.

The IMP's strength lies in its centralistic, data-driven approach: it calculates the most optimal routes for homogeneous and heterogeneous mobile robot fleets, warehouse workers, and manually operated vehicles in real time. Its user-centric design makes it easily deployable in various different industries. SYNAOS's IMP is particularly beneficial for businesses seeking AI-powered, scalable cloud solutions. The platform has been successfully implemented by major companies such as Volkswagen, Schaeffler and ZF.

Utilizing the VDA 5050 interface, SYNAOS sets high standards in integrating and communicating between different mobile robots. This capability, combined with the largest network of industry partners and mobile robot manufacturers, offers unmatched compatibility and flexibility.

Synersight

ES | 2017 | -
- AGV/AMR vendor

System Logistics

IT | 1986 | Global (Parent)
- System integrator with AGV/AMR range
- Acquired by Krones in 2016 (majority stake)

Company Profiles: How to read?

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Techvico

VN | 2019 | TH
- Navigation software vendor

Third Wave Automation

US | 2018 | -
- AGV/AMR vendor

Toyota Material Handling

JP | 2017 | Global
- AGV/AMR vendor
- Part of Toyota Group

TuskRobots

CN | 2018 | -
- AGV/AMR vendor

Vecna Robotics

US | 1998 | -
- AGV/AMR vendor

AGV & AMR VENDOR PROFILES: V-W

Versabox

PL | 2013 | -

- AGV/AMR vendor

VisionNav Robotics

CN | 2016 | -

- AGV/AMR vendor

Wagner Group GmbH

DE | 1976 | Global

- Fire safety solution vendor

MAG Mobile Automation Group

Waku Robotics

DE | 2019 | -

- Robot management software vendor

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KOLLMORGEN
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INTERVIEWS, TRADE SHOWS, GLOSSARY

INTERVIEWS - AGV & AMR HW/SW VENDORS:

- Addverb (IN) — CSO & Co-founder
- Arendai (US) — CTO & Co-founder
- BlueBotics (CH) — CEO
- Bosch Rexroth (DE) — Projects Director Robotics
- Christensen Strategy (US) — Founder
- Cyngn (US) — CEO
- E80 Group (IT) — President NA
- EZ Wheel (FR) — COO
- FlexQube (SE) — CEO
- ForwardX (CN) — COO
- Hangcha (CN) — Head of International Sales
- HMS Networks (SE) — BDM, Logistics
- idealworks (DE) — CEO
- JBT Corporation (US) — Sr. Strategist – Market Development
- Jungheinrich (DE) — Product Manager Mobile Robots
- K. Hartwall (FI) — EVP
- Karter (NL) — Commercial Manager
- Koerber Supply Chain (US) — VP Robotics & Voice
- Kollmorgen (SE) — Product Management Director
- Kontro Hertz (KR) — CEO
- Kudan (JP) — COO
- LexxPluss (JP) — COO
- Linde Material Handling (DE) — Product Manager EMEA
- MHP (DE) — Sr Manager
- MIR (DK) — VP Marketing & Strategy
- Mobotic (DE) — Founder
- Moontech (ES) — CEO
- Moving Robots (ES) — CEO
- Movizon (DE) — Director Product Management
- Movu Robotics (NL) — CSO
- Muratec (US) — National Sales Manager
- NODE Robotics (DE) — CEO & Co-founder
- OCME (IT) — Sales Director
- Okamura (JP) — Overseas Manager
- Pepperl + Fuchs (DE) — Market Manager, Material Handling
- Rapyuta Robotics (JP) — Product Manager AFL
- RGo Robotics (IL) — President & CBO
- Robot Center (UK) — Founder
- SAFELOG (DE) — Managing Director
- SEER (CN) — Overseas Business Manager
- Slamcore (UK) — CEO
- Slip Robotics (US) — VP Sales
- Standard Robots (CN) — Director of Overseas Marketing
- Starnus (NL) — CEO & Founder
- Synaos (DE) — CEO & Co-founder
- Synapticon (DE) — CRO
- Techvico (VN) — CEO
- Toyota Material Handling (SE) — SVP & Managing Director
- Vecna Robotics (US) — Director of Business Development
- Versabox (PL) — Co-founder & Board Member
- Wagner Fire Safety (US) — CEO & President
- Waku Robotics (DE) — CEO & Co-founder

INTERVIEWS - USERS & BUYERS:

Multiple companies & individuals that requested anonymity from FMCG/CPG, 3PL, Manufacturing, etc.

We extend a big thank you to these contributors!

If you want to contribute your views on the sector, please contact tom@styleintelligence.com for an informal/confidential chat

EVENTS (RECOMMENDED/VISITED BY STIQ):

- Automatica 2023 (DE) [Web]
- Hannover Messe 2023 (DE) * [Web]
- Logimat 2023 (DE) * [Web]
- Logis-Tech Tokyo 2023 (JP) * [Web]
- Modex 2024 (US) * [Web]
- Promat 2023 (US) * [Web]

*Key: * = STIQ visited/ visit planned*

GLOSSARY

3PL	Third Party Logistics
AFMS	Agnostic Fleet Manager System
AGV	Automated Guided Vehicle
AMR	Autonomous Mobile Robot
ASRS	Automatic Storage & Retrieval System
BMS	Battery Management System
CFC	Central Fulfilment Centre
CPG/FMCG	Consumer Packaged Goods (US/UK)
DC	Distribution Centre
ERP	Enterprise Resource Planning
EV	Electric Vehicle
F2F	Floor to Floor (~when moving a pallet)
F&B	Food & Beverage
Fiducial	Marker used to localise a robot
FM / FMS	Fleet Manager System
FTE	Full Time Employee
Kinetics	Vehicle drive wheel configuration
M&A	Mergers & Acquisitions
Odometry	Output from motion sensors
PCB	Printed Circuit Board
PLC	Programmable Logic Controller
POC	Proof Of Concept (trial)
RaaS	Robotics as a Service
ROI	Return on Investment
ROS	Robotics Operating System (ROS +ROS2)
RTLS	Real Time Location System
Sensor Fusion	Combination of multiple sensors
SLAM	Simultaneous Localisation and Mapping
SMB/SME	Small & Medium Businesses (US/UK)
TCO	Total Cost of Ownership
UWB	Ultra Wideband
VSLAM / vSLAM	Visual SLAM
WMS	Warehouse Management System

FURTHER RESOURCES (CONTACT US):

AGV & AMR Robotics market size data + To discuss this report or the wider sector, trends, equipment, solutions, etc. Email STIQ Ltd > tom@styleintelligence.com

SYNAOS Intralogistics Management Platform

Orchestrate mobile robots, employees and vehicles with industry-leading precision.

Enter a new era of intralogistics: a world in which errors are minimized, processes are intelligently controlled and challenges are mastered proactively. With the support of industry-proven AI technology, SYNAOS equips your processes for the requirements of tomorrow – efficient, future-proof and scalable.

Learn More

SYNAOS