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AGV & AMR ROBOTICS 2022

PALLET HANDLING + CUSTOM PAYLOADS | FACTORY & WAREHOUSE MOBILE ROBOTS | NOV 2022

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EXEC SUMMARY: STRONG GROWTH IN 1H22 FOLLOWED BY MUTED DEMAND IN 2H22. SUPPLY CHAIN ISSUES IMPACTING DELIVERY. EARLY MARKET INFLECTION SIGNALS

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AGV & AMR ROBOTS

- This report focuses on mobile robots used for transporting payloads/goods A-B (storage solutions are covered in other STIQ reports)
- The AGV & AMR Robotics sector is highly fragmented with 400+ vendors globally
- Applications for AGVs & AMRs vary from moving light 400g PCBs to very heavy 65 tonne steel coils

MARKET GROWTH

- Interviews suggested high sales levels in 1H22
- Demand relaxed somewhat in 2H22, impacted mainly by Russia's war in Ukraine and high inflation rates affecting automation plans and budgets
- Growth appeared to be a combination of new business and postponed projects from 2020/2021

SUPPLY CHAIN PROBLEMS

- Supply chain disruption from 2021 deteriorated in 2022 and became more persistent in 2H22 with extensive lead times and increased prices
- Backlogs expanded as most AGV & AMR vendors were unable to deliver
- The primary issue was supply of components and a few vendors decided to design out components to alleviate supply chain disruption; however, it was unclear if this solved delivery times

EARLY INFLECTION SIGNALS

- There were early positive signals that efforts in 'customer educational activity' had begun to transform into wider sales and raise the potential for short to medium term market inflection
- However, strained new venture capital flows and the continued absence of an AGV & AMR system integrator layer, combined with market fragmentation, could expand time to inflection

MARKET TRENDS

- Two key trends were: component suppliers consolidating functionality and agnostic fleet managers evolving into wider execution systems
- Multiple component suppliers consolidated up & downstream functionality, such as Lidar vendors adding SLAM software and chip manufacturers providing motherboards
- A number of AGV & AMR vendors also broadened their product ranges with international ambitions
- The partnering trend continued with a focus on additional and international sales channels

MARKET OUTLOOK

- The primary impression from 60+ interviews was huge uncertainty for 2023 with the war in Ukraine, inflation and interest rates mentioned frequently
- Recessionary pressures could subdue demand in the short term and, depending on the severity, could potentially affect the market in the medium term
- However, high employment levels continued to limit customers ability to attract staff and automation remained a prioritised option
- Continued supply chain problems could potentially lead to customers exploring less flexible options

AGV & AMR KEY SUCCESS FACTORS

- Senior management buy-in was viewed as a key critical success factor for AGV & AMR projects
- Equally important was proper customer market research (incl. reading STIQ reports), knowledge & cross functional project teams, and the ability to properly identify and assess all the IT systems affected and involved in a potential project

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AGV & AMR ARE MOBILE ROBOTS SEGMENTED INTO THREE BASIC FORM FACTORS: MOUSE, FORKLIFT AND TUGGER

AGV & AMR FORM FACTORS

- There are three basic vehicle form factors for AGV & AMR robots
- Each of these overlap to some extent and may be deployed in similar applications
- As the sector evolves and grows further, form factors are likely to diffuse further with less clear boundaries

MOUSE

- The mouse form factor tends to be a flat robot that drives under a payload and hooks on to it from below (tugger functionality) or lifts it (carry functionality)
- Mouse vehicles normally require payloads to be placed at a height or have sufficient space below, for the robot to fit under the payload, and additional infrastructure may be required to suspend payloads
- Navigation technologies tend to be "guided" (QR code, magnetic, etc.) or "mapped" using 2D or 3D SLAM

FORKLIFT

- The forklift is used to lift payloads, often pallets at heights between 0.5m-15m
- Forks can be exchanged for other implements to carry paper reels, coils, etc.
- Navigation technologies tend to be Laser Guided, Contour or 2D SLAM
- 3D SLAM for forklifts is a relatively new addition

BASIC AGV & AMR ROBOTICS FORM FACTORS

IMAGE	FORM FACTOR	TYPICAL VEHICLE ACTIONS	DESCRIPTION
	**MOUSE** (a.k.a. "turtle")	• Drives under a payload and either raise its own platform to carry the payload or attach to pull (tug) a payload from below	• Navigation: XY • Safety sensors: 1-2 lidar • Health & safety: Limited speeds and increased safety distances for higher payloads • Often require a platform to be built on top of chassis to connect to trolley or staging area
	**FORKLIFT** (a.k.a. "forktruck")	• Works in a similar way to a manual forklift, i.e. the forks are typically used to lift a payload from a rack or floor location • Vehicles may be fully autonomous or retrofitted manual vehicles	• Navigation: XYZ + pallet type recognition • Safety sensors: multiple lidar, camera • Health & safety: Paramount with additional complexity of forks and high payloads at potentially high elevations
	**TUGGER** (or tow vehicle)	• Pulls a trolley or train of trollies or carts • Payloads are frequently in tonnes • Primarily retrofitted manual vehicles, but fully auto vehicles exist	• Navigation: XY • Safety sensors: 1-2 lidar + camera • Health & safety: Often very heavy payloads (10's of tonnes) brings additional health & safety issues for breaking capabilities and managing long trains • Rarely require any mechanical customisation

Source: STIQ Research & Analysis

TUGGER (aka Tow Vehicle)

- A tugger (or tow vehicle) tends to be used in niche applications towing trains of trollies or trailers
- Tuggers tend to be deployed in factories for line-side replenishment (aka "Milk Rounds") but are also known to be used in warehouses
- Navigation technologies tend to be Laser Guided, Contour or 2D SLAM
- 3D SLAM for tuggers is a relatively new addition

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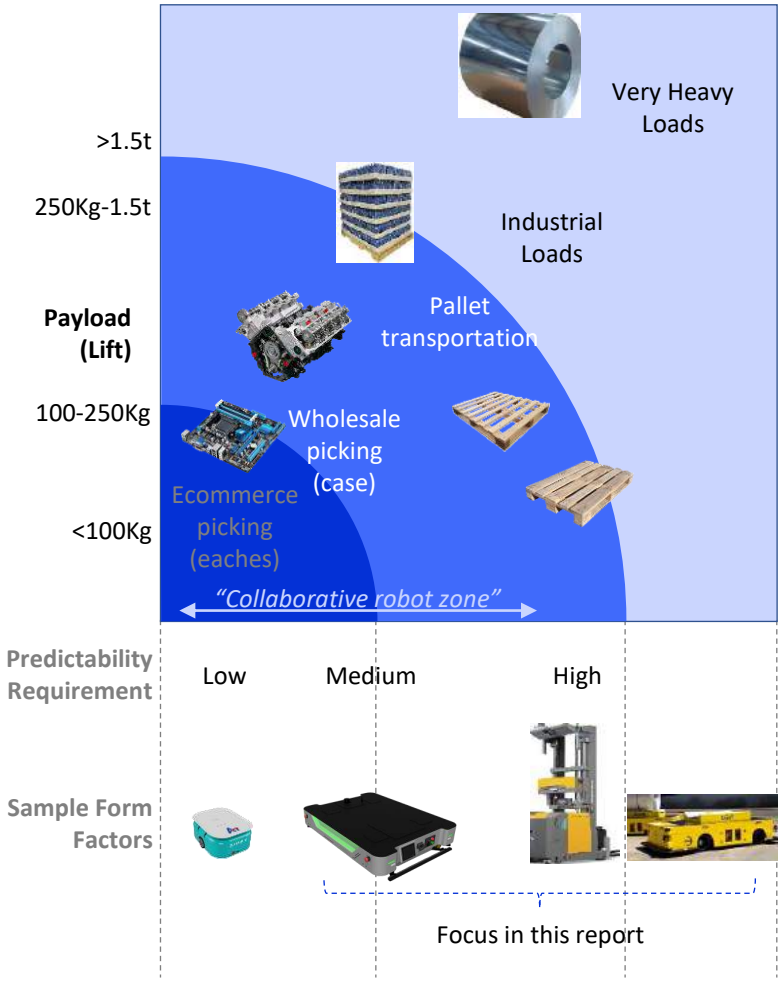
MOBILE ROBOTS ARE HIGHLY VERSATILE AND CAN TRANSPORT A HUGE VARIETY OF PAYLOADS AND GOODS ACROSS A VERY BROAD SPECTRUM OF INDUSTRIES

ROBOT PAYLOAD VS PREDICTABILITY



Source: STIQ Ltd Research & Analysis

VERSATILITY OF AGVs & AMRs

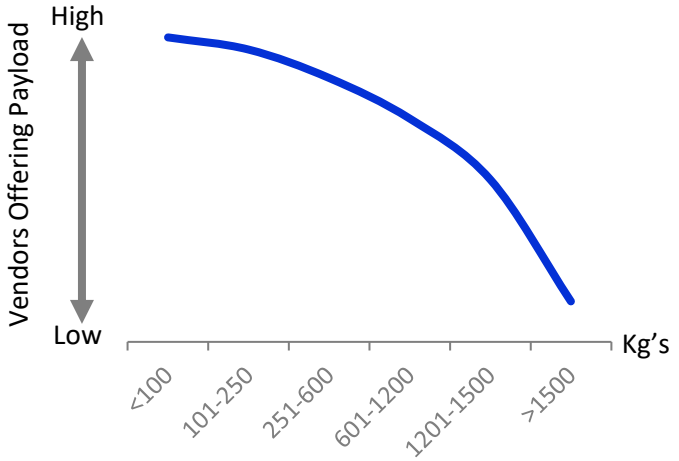
- AGV & AMR are essentially mobile robots primarily used in intralogistics (indoor logistics) applications across factories and warehouses
- There are a huge variety of applications where AGVs & AMRs can be used and, accordingly, the market can be segmented in a wide variety of ways
- Applications can be divided into horizontal and vertical
- Horizontal applications can vary from transporting 500g PCBs in an electronics factory to moving a 65ton steel coil several 100s of metres
- Vertical applications typically involve forked vehicles moving payloads from/to racking
- There are more vendors offering robots with lower payloads compared to higher and bespoke payloads

IDENTIFYING VENDORS

- The versatility of each vehicle form factor has added a level of difficulty for customers to identify suitable vehicle types and vendors for specific applications
- For example moving something one way can be called kitting, but in reverse it can be a picking application

"The first project we had for our solution was for kitting in production. It's kitting, but if you turn it around to logistics it becomes a picking solution." [Sherpa]

AGV & AMR VOLUME (ILLUSTRATION ONLY)



Source: STIQ Research & Analysis. Approximate payload levels

"There are too many vendors and they often have different technical capabilities. If a customer goes to one of the forklift companies to get an offer for an AGV or AMR from their ranges, it might be either that their offering is technically not possible or too expensive. But the downside of that is that customers might believe that's what the market is. They might believe the AGV & AMR market is precisely like the forklift market and that there is no fundamental technical differentiation. Whereas in reality there are huge differences between the technologies of the vendors." [Waku Robotics]

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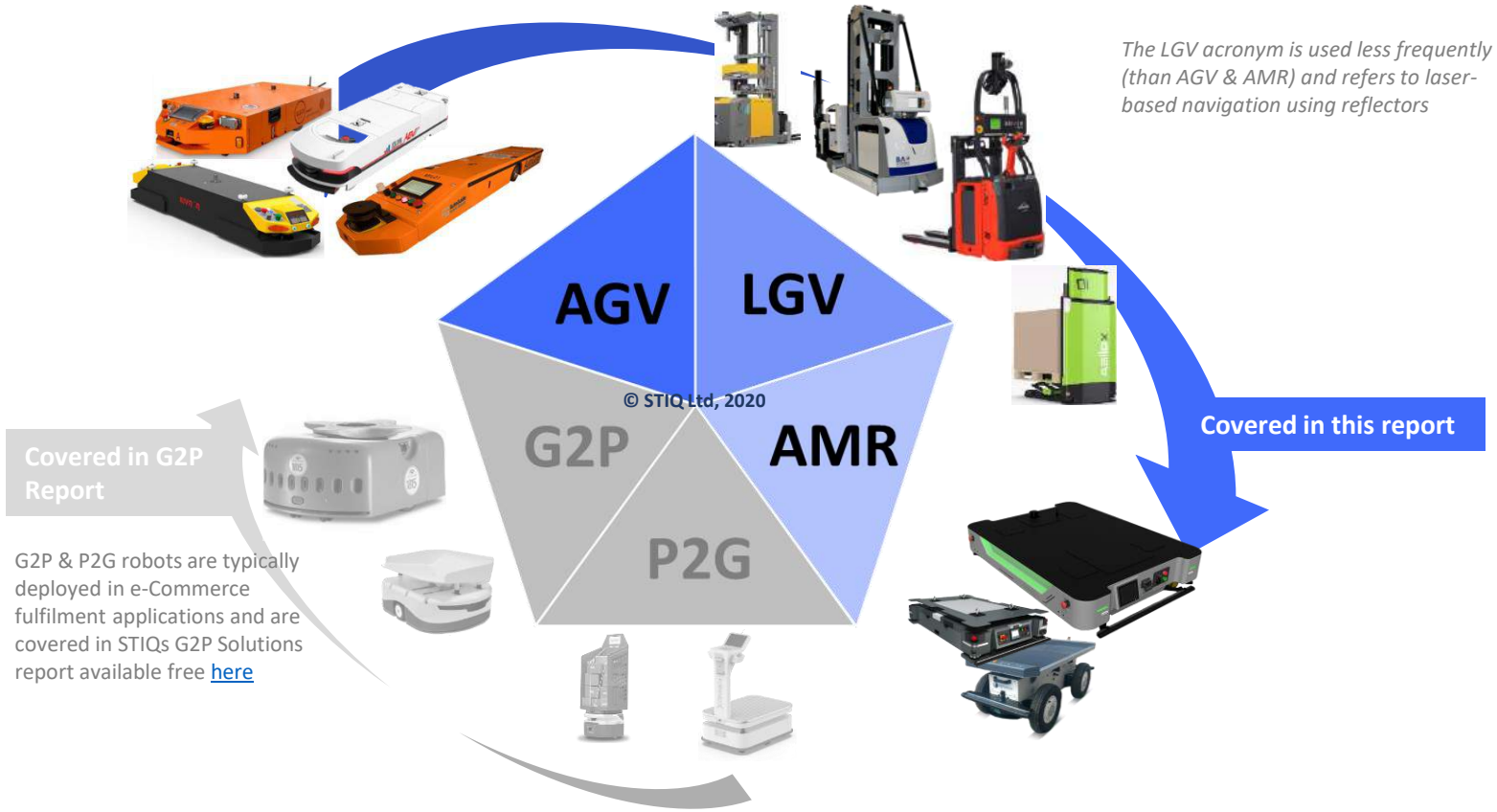
THE MARKET MAY BE FURTHER SEGMENTED BY PRIMARY NAVIGATION TECHNOLOGY, INFLUENCED BY WHEN THE TECHNOLOGY WAS INTRODUCED

MOBILE ROBOTS IN MATERIAL HANDLING APPLICATIONS (SEGMENTED BY NAVIGATION TECHNOLOGY)



The LGV acronym is used less frequently (than AGV & AMR) and refers to laser-based navigation using reflectors

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

Source: STIQ Ltd Research & Analysis

HISTORICAL NAVIGATION TECHNOLOGY

- Historical sector developments and applications have largely forged AGV & AMR market segmentation across navigation technologies
- Rudimentary AGVs first began appearing in 1950s and were applied in the automotive sector in the 1970s
- Forklift LGVs were introduced in the 1990's and AMRs using SLAM in the mid 2010s
- G2P robots using QR code navigation appeared around the 2000s, popularised by Kiva Systems (acquired by Amazon in 2013), and P2G robots appeared around the same time as AMRs
- The emergence of SLAM-navigated AMRs in the mid-2010s caused additional confusion in segmentation, i.e. "What is an AGV vs an AMR?"

G2P & P2G MAINLY STORAGE & RETRIEVAL

- Currently, G2P & P2G robots are primarily deployed in eCommerce fulfilment applications and fulfil a different set of tasks compared to AGV & AMR robots
- G2P & P2G solutions are primarily focused on storage & retrieval of "eaches" (single products, as opposed to boxes of 6s or 12s, etc.)
- However, segments and applications continue to evolve and are increasingly overlapping
- STIQ covers G2P & P2G robots in the Goods to Person Solutions report (available to download here)

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THE MANY DIFFERENT ACRONYMS AND NAVIGATION TECHNOLOGIES USED HAS HELPED CREATE A RELATIVELY OPAQUE MARKET, ESPECIALLY FOR NEW CUSTOMERS

AGV & AMR ROBOT NAVIGATION TECHNOLOGIES

	NAVIGATION TECHNOLOGY	STRUCTURED WORKFLOW	UNSTRUCTURED WORKFLOW	LOCATION TECH	ACCURACY	COST	OBSTRUCTION AVOIDANCE	VEHICLE TYPE
AMR	*Neural SLAM*	*Next gen technology (further R&D expected)*						
AMR	VSLAM (3D)	↑	↑	Camera+	↗	↗	Possible	M (F/T)
AMR	SLAM (2D)	↑	↗	Any	→	↗	Possible	F/T/M
LGV	Contour	↑	→	Laser	→	↗	Possible	F/T
LGV	Laser	↑	→	Reflectors	↑	↗	Possible	F/T
AGV	Datametric	↑	→	QR Markers	↗	↘	No	M
AGV	Magnetic	↑	↓	Magnets	↗	↓	No	M/T
AGV	Optical	↑	↓	Tape	↗	↓	No	M/T
AGV	Induction	↑	↓	Cable	→	↓	No	M/T

STIQs suggested acronym use

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

THE NAVIGATION TECHNOLOGIES

- There are many different navigation technologies used in the AGV & AMR Robotics sector
- These vary from guided (AGV & LGV) technologies to mapped technologies (AMR)
- Guided means a vehicle knows where it is based on markers/ reflectors in the ground or on walls, etc. These are also used to navigate the vehicle
- Mapped means the vehicle uses a map of the facility to identify where it is and to navigate

WHY DIFFERENT NAVIGATION TECHNOLOGY?

- Note that this is a very generic explanation; potential customers should get expert assistance for their particular application requirement/s
- There can be many different reasons for using a particular navigation technology versus another
- In some cases it can even be suitable to use more than one navigation solution, i.e. to add a level of redundancy

PREDICTABILITY CAN BE IMPORTANT

- Applications requiring strict KPIs, such as takt times, etc. often use guided navigation technologies (AGV, LGV)
- These navigation technologies tend to be more predictable as they often lack autonomy to make local navigation decisions

"Most of our customers are interested in the predictability you get from our traditional product where you want a predictable path and you don't want to take any risks. But of course there are customers interested in something else and for them, SLAM navigation and obstacle avoidance is an alternative… But when you start doing the calculations and you look at the return on performance and how many orders per hour that can be guaranteed or not… there are drawbacks with flexibility." [Kollmorgen]

- Some customers and applications have very high availability demands, often the case with car manufacturers

"A lot of times we focus on resilience and system availability. If we install a system in an automotive company, it has to work. We will fulfil whatever is requested, if its 90-95% or even 99%. But that 1% might still cause a lot of damage to our customers. The ultimate goal is to have a system that is not failing, and if it is failing, that it's not stopping the line. That means you need buffers, redundancy, and you need a simple system that a human is even able to understand." [Safelog]

** Hugely simplified*

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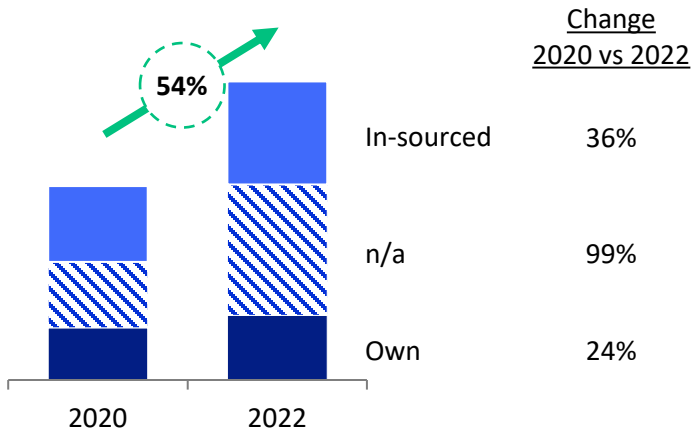
NAVIGATION SOFTWARE OUTSOURCING IS RELATIVELY COMMON

NUMBER OF COMPANIES TRACKED BY STIQ, 2020 & 2022 (BY NAVIGATION STACK)



Source: STIQ Research & Analysis. 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)

STIQ NAVIGATION OUTSOURCING TRACKER

- Use this chart with caution: It refers to # vendors using outsourced LGV, AMR navigation software, not # robots
- Furthermore, there are plenty of vendors with unknown navigation stacks
- The total number of AGV & AMR vendors tracked by STIQ increased by 54% (2020 vs 2022)
- In the same period, the number of AGV & AMR Robotics vendors using outsourced navigation software increased by 36%
- Vendors with own developed navigation software increased by 24% in the same period

NAVIGATION SOFTWARE VENDORS

- In 2022, STIQ identified 65 companies globally that provided software solutions specifically targeting the AGV & AMR Robotics sector
- About 2/3's of these provided a navigation solution with the remainder providing fleet managers, localisation stacks, integration layers, fleet tools, etc.

NAVIGATION SOFTWARE VERSATILITY

- Navigation software can be applied to a wide number of vehicle types, kinematics, applications, etc.
- Some vendors focused on specific material handling machinery types and form factors

"Our focus is forklifts. We can navigate any type of mobile robot, but we are kind of focused on forklifts and this is what we've done the most to date." [Romb]

- Commercial cleaning applications appears to be an interesting application for recent entrants

""We are pursuing mostly material handling in manufacturing and warehousing, as well as professional cleaning." [Sevensense]

"The biggest application now is in cleaning. There is demand in this sector… the logistics sector has been automated for many years and all these AMR companies are competing in the logistic sector." [Proxima Robotics]

NUMBER OF SOFTWARE COMPANIES TRACKED BY STIQ (BY TYPE OF SOFTWARE)

Source: STIQ Research & Analysis

ADDING TO WIDER FRAGMENTATION

- However, navigation software vendors were also adding to fragmentation in the market as they lowered barriers to building AGV & AMR robots
- Interviews hinted that some potential end users may be considering building their own robots

"Many large companies, large engineering companies are trying to develop their own AMRs." [Anonymous]

- However, whilst it may be easy to build mobile robots, creating robots to operate for 10 years in a factory is far more difficult

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NAVIGATION TECHNOLOGY SELECTION CRITERIA VARIES

SELECTING A NAVIGATION SOLUTION

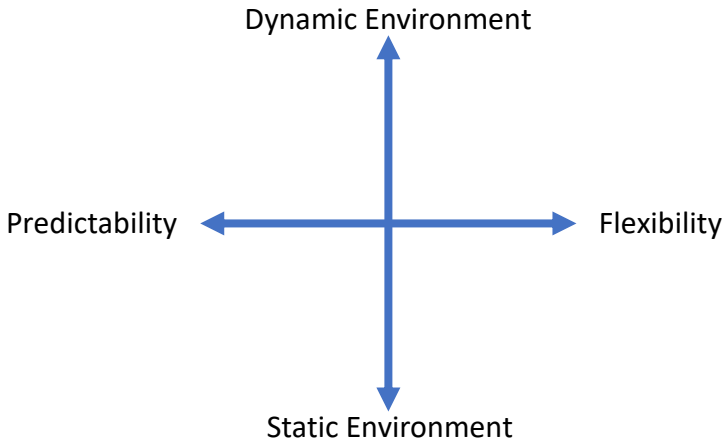
- Selecting a particular navigation solution is typically dependent on the application and the environment in which the mobile robot will operate

"The navigation technology we use depends on the application for the AGV. Maybe inside a factory you don't need SLAM because the AGV always makes the same route at the same time. It doesn't make sense to use SLAM in that case. Right now we have a project for an outdoor 65 tons AGV where we use all kinds of navigation technology, GPS, SLAM, etc. It's a project where the AGV moves a steel coil c.3.5 Km. There are no references and then we need to get the position with GPS for example. We normally fit the navigation technology to an application and to a customer and what fits that customer best for their need." [DTA]

RESILIENCE & REDUNDANCY

- Most AGV & AMR deployments are critical to business operations & success where failure and downtime may equal multi-$m costs
- In such applications vendors may opt for using a failsafe or additional navigation technology to ensure operations can be maintained with minimal (if any) disruption
- Furthermore, these applications may also include additional vehicles to ensure there is a buffer

NAVIGATION TECHNOLOGY SELECTION CRITERIA



Source: STIQ Ltd Research & Analysis

"We installed 100's of robots in a German automotive facility and they are driving on magnetic tracks, but they're also driving on contour. So if they lose the magnetic track they can go back to the track via contour navigation. We decided together with the customer that we're not going to remove the magnetic track. Because it's going to make things complicated. If people in their manual traffic cannot see where the AGV is probably going to go next then it's going to make life hard to navigate in there." [Safelog]

- There may be many different reasons for including more than one navigation technology and this may include weather considerations

VEHICLE SPECIFIC REQUIREMENTS, ETC.

- There may also be many other reasons for using a specific navigation technology
- For example, some customers want forklifts that can switch between manual and automated modes which may require different localisation technology

"Many end users of AMR forklifts prefer to mix the use of forklifts in manual and automated mode. But with a 2D SLAM solution the vehicle may not recognise where it is if the autonomous system was not turned on when the forklift was moved manually. 3D SLAM is attractive because of that, enabling them to switch between manual and autonomous mode without problems." [Kudan]

FLEXIBILITY IN DYNAMIC ENVIRONMENTS

- For some applications and/or customers, object avoidance can be important, i.e. in highly dynamic environments such as 3PLs, and may use SLAM navigation (AMR)

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NAVIGATION SOFTWARE FOR AGV & AMR ROBOTS OVERLAPPED SIGNIFICANTLY WITH AUTONOMOUS VEHICLE NAVIGATION STACKS

OVERLAP WITH AUTONOMOUS CARS

- Technology used for Autonomous Car navigation and that used in the AGV & AMR Robotics sector overlaps significantly, especially in 3D SLAM
- Component suppliers operating in both sectors leveraged technology developed for Autonomous Cars in the AGV & AMR sector

"We leverage a lot of technologies that we are developing for autonomous cars in robotics as an AV is essentially a robot. These include simulation, embedded compute, mapping and perception algorithms." [Nvidia]

- Many component, navigation SW and related SW suppliers could, or were, already active in both sectors

"Key commercial opportunities are definitely indoor AMR, not only for warehouse intralogistics, but also cleaning vehicles. And then the longer term opportunities are delivery robots and autonomous vehicles where we do have some traction." [Kudan]

"Our solution can be used indoor and outdoor. But our active customers work indoor. Let's see if it's an increasing trend for in + outdoor because many companies have these multiple warehouses near to another so it may be an increasing feature." [Proxima Robotics]

- The overlap was stronger in AMR SLAM technologies, such as Visual SLAM and 3D SLAM

"The AMR space is expanding and getting closer to the autonomous delivery vehicle. AMRs used to be mainly indoor, but now there are several companies operating in mixed environments. If an AMR can operate outdoors quite robustly and reliably, then the border between AMRs and autonomous delivery vehicles is getting even more vague, especially in localization and navigation." [Kudan]

POTENTIAL FOR MIDDLE MILE COMPETITION

- Autonomous vehicle software vendors were increasingly active in areas overlapping with AGV & AMR Robots

"We're doing a tow tractor project, the sort of thing you see in industrial sites where they're towing heavy loads. These are often used in airports… We want the system to be able to transition between an indoor and an outdoor environment." [Fusion Processing]

- Private environments were attractive as they offered a level of modularisation and lacked some of the legislative hurdles exposed in public applications

"We have sold our first airport baggage AGV. This is a single bag AGV that carries a bag for late arrivals or short connections to make sure that travellers get their luggage on arrival… which today is very often not the case, because nobody makes a manual connection between terminals just for one bag." [Alstef Group]

"I wouldn't necessarily say it's the most commercial potential of all sectors, but it's a very attractive one because it doesn't rely on legislation… tow tractors are certainly in there and they tend to be used on private ground and they don't have the legislative hurdles that we have with public road use cases." [Fusion Processing]

- STIQs impression was that the middle mile may experience significant attention in the short term
- Vendors, such as Oxbotica, Fusion Processing, Gatik, etc. already occupy "middle mile" type applications (see STIQs report on Autonomous Delivery Vehicles here)

AUTONOMY TECH STAFF MOVEMENTS

- STIQs past and current interviews highlighted there was significant movement of staff between Autonomous Cars and AGV & AMR Robotics sectors

"We get our staff from the autonomous car side and from general robotics and then we also hire people for the enterprise side from… more like SaaS style companies. Our new VP of Product came to us from Facebook and Peloton, bringing more of consumer mindset. He's got experience in the connected hardware sector… having the human in the loop in automation is really one of our biggest USP's. That's a really important feature for us and he brings a lot of expertise in that." [Vecna Robotics]

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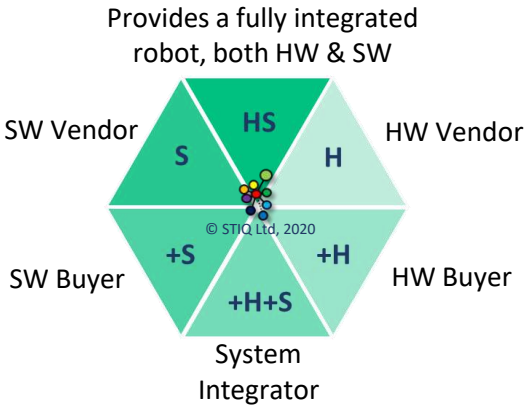
BUSINESS MODELS REMAINED FLUID

BUSINESS MODELS IN A STATE OF FLUX

- STIQ identified six primary business models for AGV & AMR vendors (see graphic)
- Interviews indicated vendors were increasingly dipping in and out of business models to meet customer demand
- There were different commercial drivers for moving across different business models, and converting manual forklifts into automated ones was an example

"Many forklifts are made for manual driving. The body of these forklifts is not that small and suited for manual driving. But an AGV forklift sometimes needs very narrow aisle to run because customers want increased storage capacity. We want smaller AGV forklift bodies to make sure they fit our customer requirements. Sometimes there is a lot of customization. Sometimes for the forks or adjustment, tilt functions and sometimes you need to add some technologies for perception. Some manual forklift manufacturers cannot do a lot of customization and sometimes they cannot do this very quickly. We want to get the supply chain or lead time advantage compared to our competitors. So that's also another reason we just started to do our own." [Anonymous]

BUSINESS MODELS IN THE AGV & AMR ROBOTICS SECTOR (SIMPLIFIED)



Source: STIQ Research & Analysis. 2021 AGV & AMR Robotics report (here)

- Chasing higher profitability can also be a driver for change

"We switched from an OEM manufacturer 2 years ago. Of course, it doesn't bring much profit or development for ourselves. So currently we just do OEM for some of the big companies. And actually we have positioned ourself as a manufacturer of AMRs. In this process, we actually gave up many customers. So in two years we have experienced rapid growth that surpassed the business performance of our former clients." [Aiten Popifyindustrial]

- There were also indications some robot manufacturers were evolving into solution vendors

"We probably haven't launched any new AMR robots in the last six months. I'd say we are trying to do more with the robots we have. Because we realize that we've done quite an extensive amount of integration and customization and we are trying to push more towards how do we utilize all the things we invented in the past. But, there is a lot happening on the software side I would say. So even though the form factor hasn't changed, the software has improved week by week." [Geek+]

CUSTOMERS MAKING OWN VEHICLES

- A few AGV & AMR customers have also decided to develop their own robots, especially a few companies operating in the German Automotive sector

"We decided to start developing our own product 4 years ago. From the beginning we felt very confident and, let's say, conscious that we are offering a good product. We have it running in our own plants for a bit more than 3 years now, they are performing very well. We are very happy with them. Of course, if you have own vehicles running in your plants and to make it really valuable for outside customers then it's a bit more effort, but that's what we did. In the beginning of 2022 we made it public and started our marketing campaigns." [Continental]

- As a side note, the German Automotive sector (VDA) also developed the VDA5050 standard for AGV & AMR robots

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SIGNIFICANT MARKET GROWTH IN 1H22, BOYUANT DEMAND

2022 QUARTERLY MARKET GROWTH INDICATOR

1Q22	2Q22	3Q22	4Q22e
↑	↗	→	→

Source: STIQ Ltd Research & Analysis
Key: → = same as previous year

ACTIVE MARKET + GROWTH 2022

- Note that interviews for this report were conducted in Sep & Oct 2022
- Overall, interviews indicated good growth in 2022 and there appeared to be more y-o-y project inquiries
- STIQs impression was that business in 2022 was a combination of new business and restarted projects from Covid lockdowns

"We're working on more projects now than in the same period last year. Raw material prices, especially for steel used in storage racks has stabilized to mid-2020 levels. This has helped projects to restart. There are also situations where people just can't wait and they come to a point where they just need to go. We see that coming now and a couple of projects starting off… it's not only one or two. It is really a bunch of projects." [Alstef Group]

- The automotive sector appeared to have returned to normal

"2021 was ok, not wonderful. 2020 was not great because our dependency on automotive and they did not know where they were heading with lockdowns. So they paused investments. 2022 was more like a regular year." [Kivnon]

- Component manufacturers also reported a good level of incoming inquiries

"We currently receive a lot of inquiries. From companies working on a new project with a new vehicle or where a manufacturer wants to replace maybe a Chinese product or have a more efficient available product." [Ketterer]

SIGNIFICANT BOOM IN 1H22

- Many interviews highlighted significant demand in 1H22 with signs of calming demand since summer

"Demand is back to normal. It was extraordinarily high in the first half of 2022… in Q3 we found people are a little bit more careful..." [MIR]

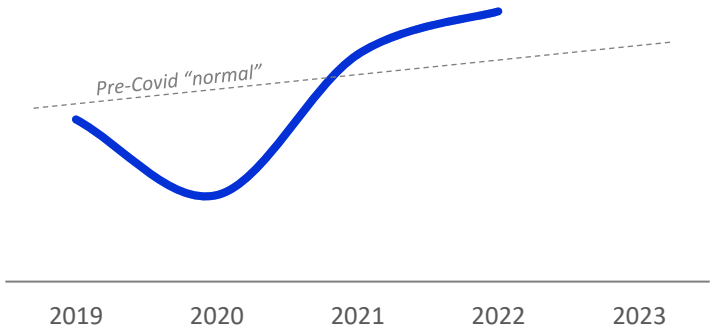
"We saw a big boom in the first half of this year... compared to H1 of last year, we actually increase roughly about five times in terms of order for controllers. Most of them go to Chinese vendors, but there is a portion of their robots also sold to the international market." [SEER]

- Interviews suggested record order intake

"The first quarter this year was the highest peak ever. Then there has been a slow down mostly in Europe. I think also as a consequence of the war crisis and inflation. But on a worldwide basis we've had a continuous flow for order intake and so far in the month of September we are already meeting, our budget for this year with three months to go." [System Logistics]

"In 2021 we grew 50% over 2020 and at this point we've already doubled on 2021. Q3 is looking strong… it'll be interesting to see what happens with Q4." [Vecna Robotics]

ILLUSTRATIVE SECTOR GROWTH, 2019-2022



Source: STIQ Ltd Research & Analysis. Not to scale
Note: STIQ also offers market size data – contact for more information

TREND: BIGGER AND LARGER?

- An interesting trend in 2022 was many vendors selling larger projects and/or bigger robots

"We do see a larger mix of the high payload robots. The larger robots are taking a higher proportion of the product mix. Unit growth is not that big, but revenue growth is in line with expectations." [MIR]

"We're not selling more vehicles, but the single AGVs, let's say we sold more of the bigger ones than the smaller ones." [Safelog]

"In terms of AGV, we have a good backlog due to the big order intake in 2021. In the previous year we sold very big projects and we are moving towards selling a larger number of vehicles in less plants. Part of the reason for this is bigger factories, but also new functionality that we are implementing with our AGVs." [System Logistics]

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HOWEVER, DEMAND VARIED SIGNIFICANTLY BY INDUSTRY SECTOR AND GEOGRAPHY

2022 MARKET GROWTH INDICATOR BY SECTORS

Demand	Sectors
↗	• Pet Food, Electronics, Semiconductors, Battery, Pharma
→	• Automotive, Grocery
↘	• F&B, Retail

Source: STIQ Ltd Research & Analysis
Key: → = same as pre-pandemic

VARIATIONS IN DEMAND BY INDUSTRY

- Demand varied significantly by location and industry throughout 2021 and 2022
- This appeared to be primarily influenced by geopolitical events and continued Covid restrictions in some countries

"Last year it was a bit slow in Europe & North America but very busy in Asia. Now it's the inverse. It looks like it will continue being a bit unstable in at least China & North America. We view Europe as the most stable market. It probably differs in individual countries. Some of the main blockers now are of course component shortages and we also have the slowdown effect that even if we've actually been able to keep our on time delivery to all our partners, there may be other components that are needed from other suppliers." [Kollmorgen]

"The war in Ukraine has stopped some projects in Eastern Europe. But we see growth across the board in the US, Europe and APAC. But it is going from everybody just wants to automate, to we need to fight a bit more for the orders as people are getting a little more cautious in Q3 about starting projects." [MIR]

"Generally speaking it's been good for us to have the highest order intake ever for the company despite inflation and some crises, and decision to hold back, especially in Europe. But in other countries the market is booming. There are countries like US that are less sensitive to inflation. So all in all already with the highest order intake ever for the company, and the forecast is in the next months to get even more orders." [System Logistics]

"Pharma is always doing well. Some of our customers are suppliers of Covid medication. That's doing well. Luxury goods and high value cosmetic is also doing well, very well. These are areas where we are doing good." [Alstef]

- However, some variations may also be due to the maturity of markets as well

"We have started interacting more with European companies where it seems their requests for VNA's are far greater than American companies we've worked with." [Third Wave]

- Some uncertainty appeared to have impacted customers

"We would have liked the industrial segment to grow faster than the warehouse automation business because it's still a little brother to that. In theory, it should grow faster. China is still a big market for us for manufacturing and it's just a highly competitive sector. Plus, in the last six months, Chinese customers have become more worried about the economy and the uncertainty has been increasing in China." [Geek+]

AND, WHEN AMAZON SNEEZES…

- The eCommerce fulfilment sector is a less dominant target customer for vendors in this report
- However, when large material handling automation buyers, such as Amazon, reduce orders, it impacts the wider material handling market

"When Amazon sneezes, the industry has a cold. Everyone sees Amazon as a bellweather of what's going on in the industry, and rightly so. Amazon invests very smartly, including walking away from investments when the total cost of doing so is lower in the long term." [Addverb]

- Multiple media reports suggested Amazon may have over-expanded during the pandemic (Source)

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SOMEWHAT SUBDUED DEMAND IN 2H22 AS CUSTOMERS IMPACTED BY COVID, WAR, INFLATION AND INCREASED POTENTIAL FOR RECESSION

AGV & AMR vs MATERIAL HANDLING SECTOR GROWTH

	2H21	1H22	2H22e
AGV & AMR	↘	↑	→
MATERIAL HANDLING	↑	↘	↘

Source: STIQ Ltd Research & Analysis
Key: → = same as pre-pandemic

DEMAND SMOOTHING OUT IN 2H22

- Interviews suggested demand in 2H22 was not negative but rather smoothed out from a high first half

"In 2021, it was just order everything you need to get us ahead of the curve here. Now, capital budgets are being more scrutinized as the economy is having inflation issues and it's having an effect on consumer demand, which is also driving demand for warehouse space and automation, etc." [Addverb]

"Demand was pretty strong in 2020 & 2021. In 2022, I think that things are smoothing out a little bit." [Anonymous]

"I don't think demand is shrinking. It might be growing less exponentially than it used to, but I still see a significant growth in demand." [Geek+]

"2020 was ok… 2021 was crazy. We now see the volume per customer growing more steadily." [Accerion]

- The pandemic continued to influence the market

"We recognize on one hand that demand for automation is very high because the lack of workers. On the other hand, all the crisis such as Corona... let's say it's not over entirely yet… The market appears a bit, let's say a bit more careful." [Continental]

- Interviews also suggested customers appeared to do more research and diligence on projects
- This could also be evidence of increasingly cogent procurement processes of mobile robots

"Another factor that may be looming is the speed with which people are buying is slowing. It's not because they're not going to spend the money, it's because they want to do more vetting. Because the options are vast. People are getting smarter about what they buy, which is great. But it may be slowing them down a little, they're doing their homework more." [SVT Robotics]

RECESSION INCREASINGLY LIKELY

- A recession appeared increasingly likely at the end of 2022 which presented significant unknowns for many interviewees

"A recession is likely coming. The big question is if this recession is small, which would be ok. Even if the market calmed down a little, demand should stay strong. If we have a huge recession, this would be another story. It would delay projects more, and probably even lead to cancelled orders. But, recession or not, this will not change the ongoing need for automation, but the question is the problem will stay six more months or three more years. This we don't know." [BlueBotics]

"From a macro perspective we're probably heading into a slight recession. But it's kind of a weird recession where it's still a tight labour market at the moment and rates are still getting higher. Everything that we've heard from our customers is that automation will continue to be a priority. Maybe growth rates will slow down, but I don't think it's going to grind to a halt by any means." [Vecna Robotics]

"It's harder for people to make decisions when there is a looming recession, but I think labour rates are not changing either. Amazon are putting warehouses across the country, I know that there is talk about them stopping a lot of their orders to key vendors. But wage rates are going up. There's continued pressure for warehouses and finding labour is harder and harder." [Addverb]

- However, despite the high potential for a recession, the longer term trend was clearly growth

"We have focused on the hub wheel drives for all kind of AGV applications over the last decade and definitely see a growing market within that customer segment. There's a lot of competition around us but nevertheless there is a also a growing market." [Ketterer]

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HIGHLY UNPREDICTABLE OUTLOOK FOR 2023. BOOKINGS VS DELIVERIES A KEY CONSIDERIATION

UNPREDICTABLE OUTLOOK FOR 2023

- Interviews suggested a fairly unpredictable outlook for 2023

"My guess would 10-15% growth in 2023. Robotics is growing at between 8-10% globally. Intralogistics are running at 30% per year… I mean it could be even the opposite in 2023." [Kivnon]

"I think the mobile robotics market is growing, maybe not 20%, but 10%." [Bosch Rexroth]

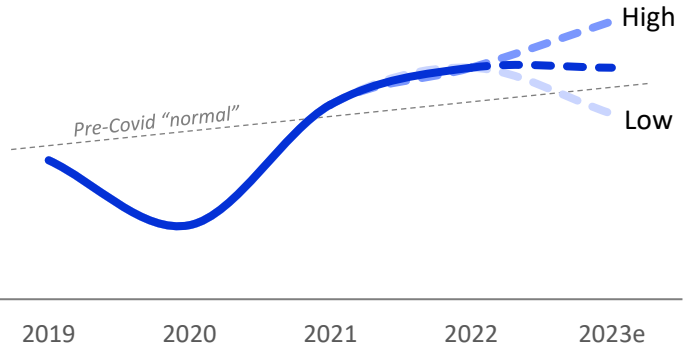
"Market growth might slow down and it might hit revenue when things get delivered. But I think that bookings will continue to go up at a healthier but slower rate than in the past." [Vecna Robotics]

GROWTH BOTTLENECKS: ABILITY TO DELIVER

- Many vendors secured good order bookings in 2022, but there were concerns about medium term growth prospects and potential for further supply chain disruption

"We are having a very good year and have as many orders already for the next year as all the turnover for this year. The problem is that you don't know how the market will go. Should we hire more people in engineering and purchasing? It's a big risk. Then the supply chain as you know it's a mess. We are trying to stock the most critical components and elements, but nevertheless, for example if we have a larger order it could be a problem to deliver very fast." [DTA]

ILLUSTRATIVE SECTOR GROWTH, 2019-2023e



Source: STIQ Ltd research & analysis. Not to scale
Note: STIQ also offers market size data – contact for more information

EXPANDING BOOKINGS VS REVENUE DELTA

- Interviews indicated high demand, but also that supply chain issues might cause bottlenecks with delivery peaks in the near future

"It's booming like crazy, but delivery continues being delayed so you have a huge amount of things that should be delivered one day in the future. But for this, of course our customers need to find all the components. Sometimes they're struggling with sensors, with motors, with whatever. It's not only one component. Some robot manufacturers we have talked to are not delivering the vehicles… vehicles are ready at 99% with 1-2 components missing and this is again delaying everything. So that's the struggle the market is having right now." [BlueBotics]

- Extensive or further delivery delays will expand the Bookings vs Revenue delta for many vendors

MANY DIFFERENT VARIABLES

- Growth in 2023 will depend on many different variables, including any component supply chain issues

"Especially in the AGV business, SICK is solidly growing on top of 2021. The extraordinary order entry will give us some challenges for 2023 to accomplish orders in time. So, it is obvious that there are remaining backlog demands due to the pandemic situation of the past 2 years. 2022 seems to have recovered the whole situation and it looks like most of the manufacturers are completely booked out - which means they are ordering beyond any expectations. But this brings us to another remark, which should not be underestimated, as many new manufacturers are entering this fast-growing market and trying to sell their solutions. It seems that the number of mobile robotic Startups is exploding worldwide. All of them are having a high demand for components for mobile solutions." [SICK]

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INFLATIONARY PRESSURES ON RAW MATERIALS OFFERED AN INDIRECT IMPACT ON THE AGV & AMR ROBOTICS SECTOR

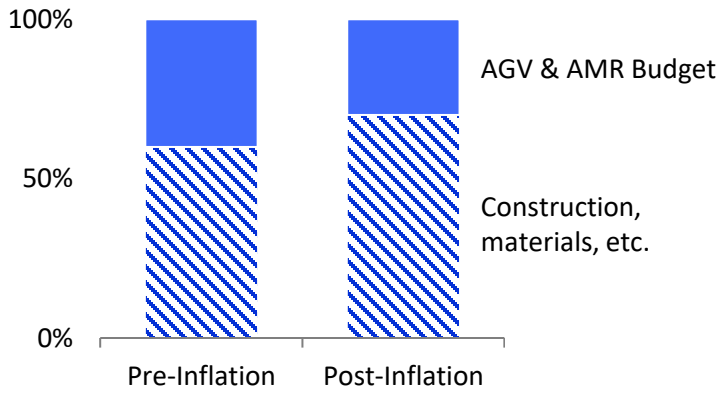
INPUT PRICES, ANOTHER FACTOR

- There are many different direct and indirect variables that may impact the AGV & AMR sector, for example the cost of warehouse construction materials

"We currently do not see any change for 2023. But that may be because budgeting was done last year, and businesses do now have money and make investments. However, we are discussing projects for 2023 and 2024. I did observe some customers were slightly insecure about their investment decisions because they do not get committed quotes for their buildings. So, they say that they don't know if the building is going to be +/- 20% and that prevents them from undertaking other investments. That's because they get quotes and building materials are indexed, meaning the wood or steel price can change. And even if we commit to our prices, they say that it's still +/- 20% for the overall investment. We have seen this happening twice now." [Körber Business Area Supply Chain]

"Raw material prices are higher, electronic materials, etc. And some customers are struggling to justify their business cases because they also have raw material increases, especially in F&B. We had a customer where we needed to delay the production because they were unable to get containers for their jam due to the war. Price increases are not only related to AGVs, but also on buildings, steel, concrete, wood stuff like that. So we had some disruption. Customers are not stopping projects, but some are definitely postponing starts." [Alstef Group]

WHOLE PROJECT INFLATIONARY PRESSURES (ILLUSTRATIVE)



Source: STIQ Research & Analysis

- Some new-builds have included automation as a part of the overall budget
- Buildings are prioritised as they house all operations and as construction materials + other costs increase, this may put a squeeze on equipment, such as automation and AGVs & AMRs

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A FEW VENDORS WERE PRODUCING MOBILE ROBOTS TO STOCK. INDICATION OF A GROWING MARKET WITH SOMEWHAT UNPREDICTABLE, VOLATILE DEMAND

PRODUCING ROBOTS TO STOCK

- An increasing number of vendors indicated they were producing robots to stock

"We are producing AMRs to inventory as well." [Addverb]

“Previously we’re were only producing to order but we are turning that to have a mixed model with some robots in stock. Our biggest market is by far the B2B environment with the higher payload requirement. So this is what we are producing in stock.” [iFollow]

- Reasons for producing to stock varied and also the level of stock holding
- The primary driver appeared to be a level of FOMO (fear of missing out) on projects with very short delivery times

“Yesterday I was talking to a large 3PL customer and they were talking about a project with 18 months lead time. For that you don’t need to produce to stock. On the other hand, I talked to the same 3PL for another project and they would like to go live before Christmas with that solution. Then of course lead times are very important.” [Addverb]

- However, it was also an improved understanding of demand for robots

“I think ever since Covid hit, the ripples on a lot of this started. So we have been planning ahead of time and are also looking to… we are in the process of building inventory of bots. So stocking inventory because we've got a fairly good understanding of what the sales forecast looks like.” [Addverb]

- Some vendors focused on keeping stock of lower payload robots whilst others produced chassis for stock to improve final build times

“Unlike some of our competitors, we do not have one or two products, but we have a range. So we also have to pick and choose a bit. For our Dynamo 200, we would then produce only the bottom part on inventory because that's the part that is common for everything. So then I still have time to put whatever is needed to put on top, which doesn’t need a long lead time.” [Addverb]

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LACK OF LABOUR CONTINUED AS A PRIMARY MARKET DRIVER, BUT ROI CHALLENGES REMAINED

LACK OF LABOUR, A KEY MARKET DRIVER

- Lack of labour continued to be a key market driver
- In many cases this is no longer an issue about affordable labour, but actual access to labour

"It's so tough to find people in a logistics environment in general… also pickers, packers and specifically for those specific position here where you need very specific skills, it's even more challenging." [Anonymous 3PL]

- Increasing labour costs were not isolated to North America and Europe, but also affected other countries

"In Japan there are a lot of suppliers for QR AGV and SLAM robots and their technology is also very good. But we would say the hardest point for domestic vendors is cost control… But also there is a lot of competition between Chinese suppliers in the Japanese market. So almost all the Chinese companies, when they want to go out to other markets, the first step is South Korea and also Japan markets." [IPLUSMOBOT]

"A warehouse worker has increased from $15 per hour to $22 so actually a lot of the US owners of factories or warehouses, they want to make automations to make up for the increasing of salaries. We still think despite the Covid spread all over the world that the automation requirement is actually increasing." [VisionNav]

- The Chinese market also lack labour but with other dynamics in play as well

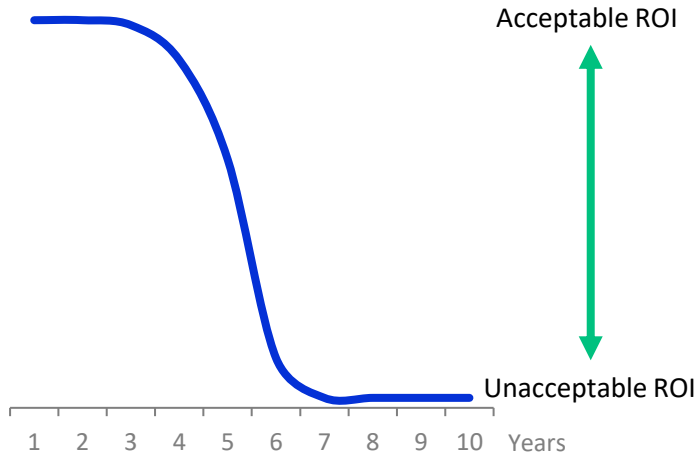
"We attended a show in China recently and it was just full with companies making all sorts of AMRs. That space has been growing rapidly. These companies can actually make money within a year because the demand is so high. I think the main driver is just shortage of labour, which is, believe it or not, true in China too. And China has scale right throughout the supply chain. To get the scale and efficiency you need robots ultimately. And because a lot of the distribution centres and warehouses were just built from the ground up... everything is new, including the software, the systems… it's easier to immediately install automated solutions… versus Europe or North America where you can't build a new factory overnight. You have to deploy into existing buildings." [LS LiDAR]

ROI AND CHALLENGES WITH AUTOMATION

- Implementing robots is not always straight forward, especially in existing building and ROI can be very challenging

"There are a lot of challenges when we do reengineering projects in existing sites. Bringing in an AGV there is usually very tough. The current layout limits us a lot. Because we have aisles from 10 years ago with 3m wide aisles. Because that was enough for manual… but for automated we need 3.20-3.30m. It's just those 20cm's but the ROI is killed… because there are also additional costs and that's what limits us. So the use case itself may have a positive ROI. But then you need to add those add-on costs like moving racking. And this is what currently limits us." [Anonymous 3PL]

ACCEPTABLE ROI ILLUSTRATION



Source: STIQ Research & Analysis

- ROI can often extend beyond 3,4,5 years but projects are typically killed off when ROI goes beyond 5 years

"When it comes to ROI what we still see is that those three years are quite tough. To be honest it's really something challenging. Sometimes when we calculate it, it can be as high as 6-7-8 years, which sometimes happens and then, of course, the project dies." [Anonymous 3PL]

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RAAS (ROBOTS AS A SERVICE) IS GAINING TRACTION, BUT IS PRIMARILY OPEX FORMATS SUCH AS LEASE RENTALS

THE RAAS REVENUE MODEL

- RaaS (Robotics as a Service) is increasingly marketed by vendors who often refer to a fixed monthly fee – an Opex revenue model, such as a lease or a rental
- A few companies appeared to be relatively successful with the lease/rental definition of RaaS

"We've been doubling down on RaaS for a while. RaaS is the vast majority of sales this year and it was something like ¾ of sales last year. From that perspective, taking on that SaaS style, we're treating ourselves like a software company, yes." [Vecna Robotics]

- Leasing companies were increasingly targeting the AGV & AMR sector

"We have a dedicated industrial section which covers logistics. This performs part of the robots, AGV and AMRs sector as well as standard forklift trucks, production machinery and everything else that a business requires for handling or manufacture. We see it as a growth sector… as I'm sure everyone else does. The plan for us is to enable customers and vendors to a degree of How to penetrate that marketplace with an offer that allows them to spread the cost." [CHG Meridian]

- RaaS may impact the market size (in the short to medium term) with higher # volumes and a lower $ value

OPEX BUSINESS MODELS

	LEASING ("renting")	RAAS
Charging Model	• A set monthly fee	• Per agreed activity; a pick, load delivered, distance driven, etc.
Requires	• Total solution cost	• Vehicle or solution data
Customer Benefits	• No CapEx. Cashflow preservation. Spreads out cost over a set period of time.	• No CapEx. Cashflow preservation. • Continuous system improvements. Pay only when used

Source: STIQ 2022 G2P Report

STIQ & THE RAAS REVENUE MODEL

- STIQs view is that RaaS should refer to a "pay per action" revenue model where customers pay for a pre-agreed action a robot performs, such as moving a pallet
- Let's say a customer pay $1 per moved pallet and moves 10 pallets in a day, then they pay $10 for that days work
- This would incentivise vendors to provide a robot service that performs as much work as possible for customers
- However, this model remains in its infancy and few robot companies offer a "pure RaaS" model

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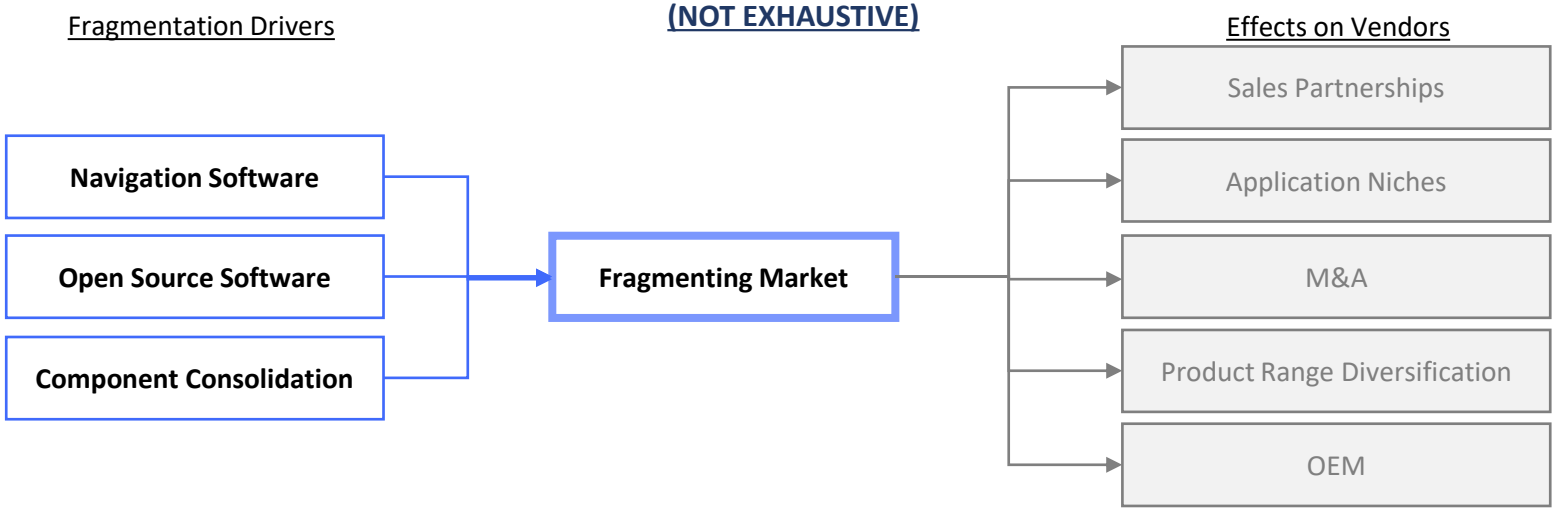
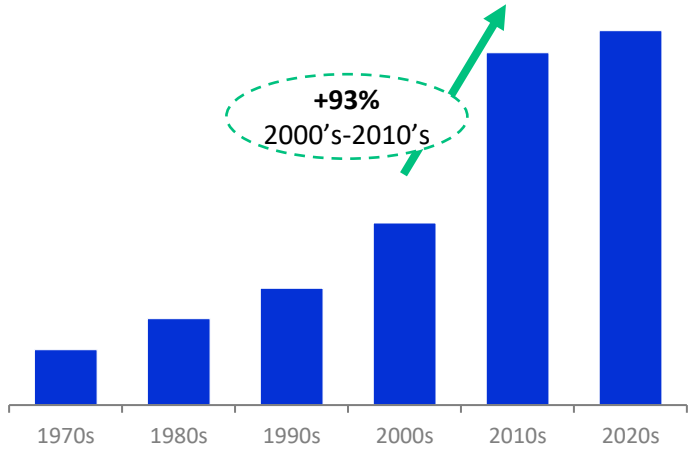
CONTINUED MARKET FRAGMENTATION DRIVEN BY TECHNOLOGICAL DEVELOPMENTS, SUCH AS OPEN SOURCE + NAVIGATION SOFTWARE AND COMPONENT CONSOLIDATION

INCREASING FRAGMENTATION, CAUSES & EFFECTS (NOT EXHAUSTIVE)



Source: STIQ Research & Analysis. Not an exhaustive overview

AGV & AMR COMPANIES BY DECADE FOUNDED, 1970s-2020s (AGGREAGATED)



Source: STIQ Research & Analysis. Decade company was founded. Companies tracked by STIQ Ltd

CONTINUED FRAGMENTATION

- The global AGV & AMR Robotics market experienced accelerated fragmentation in the 2010's
- A key driver for this was open source software, such as ROS (link)
- Furthermore, building robots will become easier in the short term as supply of component level hardware, services, and software, such as navigation packages, continues to consolidate

PRIMARY CAUSES FOR FRAGMENTATION

- Historically, increased fragmentation was caused by Navigation Software vendors selling to manufacturers of electric vehicles and system integrators
- ROS appeared in the mid 2010s and accelerated fragmentation processes in the AGV & AMR market
- More recently, component consolidation has made the process of building mobile robots even easier
- Component consolidation is when mobile robot components are bundled into ready-made packages, often with pre-curated list of sensors, motors, etc.

AGV & AMR SECTOR EVOLUTION

- The AGV & AMR sector has gone through huge technological developments in the last 5-10 years

"There has been huge technological steps in the last 5yrs. Components have become cheaper for localization and navigation. My first AGV project was at Land Rover in Solihull in 2000. There was no VLAN, no Wi-Fi so we talked to all these AGVs by radio frequency and that was not easy because Solihull is very close to the Birmingham Airport. We had to get a license to communicate with these AGVs. The sector has come a long way since then." [Sherpa]

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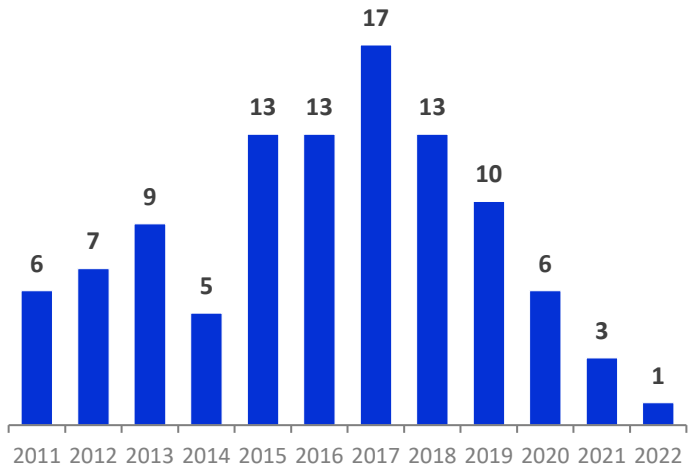
LOWER BARRIERS TO ENTRY IN THE AGV & AMR SECTOR HAS BROUGHT MORE STARTUPS. BUT VOLUME OF COMPANIES ENTERING THE SPACE ARE IN DECLINE

AGV & AMR STARTUPS BY YEAR FOUNDED, 2011-2022 (#s)



Source: STIQ Research & Analysis. Company foundation year. Does not include pre-2011 companies. Includes companies offering Mouse, Fork and/or Tugger robots

LOWER BARRIERS TO ENTRY

- Lower barriers to entry in the 2010's led to an influx of new entrants in the AGV & AMR Robotics sector
- The low number in 2014 was most likely a response to a high number of new entrants in 2013, possibly due to Amazon's acquisition of Kiva Systems
- New entrants peaked in 2017 and there has been a distinct decline in new entrants since
- The cause for this was not entirely clear, but may be partly due to STIQs methodology and also that new entrants remain in stealth for a few years
- STIQs data was based on year founded; new entrants may have been founded before 2010, such as a forklift manufacturer founded in 1967 that added AMRs in 2017 and would be listed as joining in 1967 rather than 2017
- Manufacturers of electric vehicles can quite easily spin up new AGV & AMR Robotics divisions without any significant IT resources
- Navigation software vendors offered related hardware as a package to make it easier for such companies to add mobile robot functionality quickly

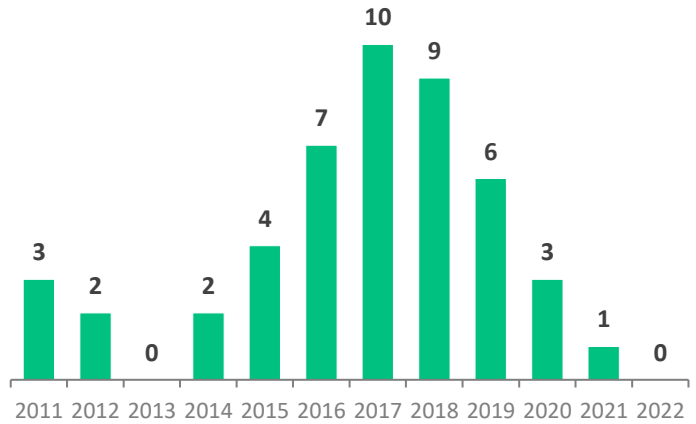
WHY DECLINING NEW STARTUPS?

- Whilst the AGV & AMR market may be reaching high saturation levels, this is unlikely to be a primary reason for the declining number of startups
- A more likely cause was that new startups remained in stealth, or lacked marketing budgets for longer
- However, STIQ interviews for this report indicated startups were increasingly seeking out niches or adjacent sectors/segments where traction was more immediate
- For example, creating Navigation Software for an AMR was very similar to a cleaning machine and at some level differentiating between these two vehicle applications can be a subjective definition issue

AGV & AMR SOFTWARE STARTUPS

- In the 5 years 2017 to 2021, 60% of startups in the sector focused on software
- Most of these software companies focused on SLAM navigation stacks and/or Fleet Management solutions

SOFTWARE VENDORS IN THE AGV & AMR ROBOTICS SECTOR BY YEAR FOUNDED, 2011-2022 (#s)



Source: STIQ Research & Analysis. Company foundation year. Does not include pre-2011 companies. Includes companies offering any type of software

- Other software solutions have mainly focused on making it easier to deploy, integrate and/or operate mobile robots
- The influx of software startups has partially been due to the release of open source software packages

DOES STIQ EXPECT AN UPTICK?

- The overall number of companies is likely to increase with Navigation Software vendors pushing sales further
- It was likely there will be more startups, but perhaps not at 2017 levels

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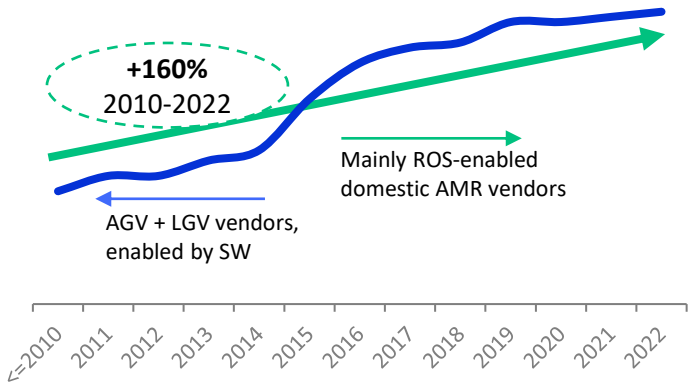
THE CHINESE DOMESTIC MARKET HAS 100'S OF AGV & AMR ROBOT VENDORS, NEARLY TWO-THIRDS FOUNDED IN THE 2010's

CHINESE AGV & AMR VENDORS, 2010-2022 (AGGREGATED)



Source: STIQ Research & Analysis. Stated HQ in China

FAVOURABLE DOMESTIC CONDITIONS

- Market conditions in China have been, and continue to be, extremely favourable for AGV & AMR vendors, especially domestic vendors
- Encouraging conditions include a high level of new factory & warehouse construction with automation strategically included in early building planning phases
- Few European and North American vendors have managed to penetrate the market

HIGHLY COMPETITIVE GROWTH

- Near optimal conditions in the domestic market has led to huge growth in the number of vendors targeting all kinds of mobile robot applications
- One consequence has been a hugely competitive market environment with loss making projects known to feature regularly for keen vendors
- Based on company foundation year, the number of Chinese AGV & AMR businesses tracked by STIQ increased by 160% between 2010 and 2022
- STIQ tracked c.100 Chinese vendors in 2022

GROWING INTERNATIONAL AMBITIONS

- Increasing competition in the domestic Chinese market has also influenced some vendors to take aim at international markets

"In China we have more than 100 AGV & AMR suppliers. Everyone wants to get the project. So that for every opportunity we could see more than 3-4 suppliers trying to compete with each other. Almost all the Chinese players plan for more than one project sold at a loss per year. It's the domestic problem right now. That's also the reason why all the Chinese suppliers want to find a way to expand overseas market." [IPLUSMOBOT]

"There are nearly 200 AGV & AMR manufacturers in China. About 10% of them are trying to be international businesses." [Anonymous]

- Some businesses are increasingly pressurised to go international, others have always aimed for overseas business expansion

"From the beginning of last year we started to develop the overseas market. We started in some Asian countries and actually we got several big projects and big customers in 2021. This year we raised another 2 rounds of funding. We still think for the overseas market there is an increasing requirement for automation. A lot of the companies or factories or warehouses are lacking the workers and also the salary per hour is increasing greatly." [VisionNav]

"For the overseas market, we decided to expand and explore the market since last year. We started to do overseas business and set up with system integratorsat the beginning of this year. So we have traded overseas for half a year or a little bit longer." [IPLUSMOBOT]

"We did try to get into the US market 3.5 years ago but then COVID hit and we changed our plans, went back and did some more R&D and made the products better. Now after Covid kind of subsided and we raised additional funding, we came back and started to really ramp up our presence in the US." [Anonymous]

Note that STIQs definition of AGV & AMR Robots may differ from that of interviewees and whilst there may be 100's of vendors in China, many or some of these may be segmented into other STIQ reports, such as G2P Solutions, etc.

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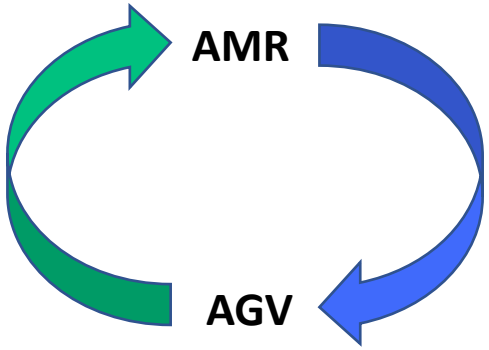
IN A SATURATED AND FRAGMENTED MARKET, FUNDAMENTALS OF MATERIAL HANDLING THEORY AND WORKFLOWS MAY BE MORE IMPORTANT THAN EVER

AGV VS AMR – FULL CIRCLE, SAME CHALLENGES?



Source: STIQ Research & Analysis

RARELY DIFFICULT TO BUILD ROBOTS

- Mobile robots were rarely difficult to produce
- For example, to build a "line guided" AGV 10 years ago, a vendor simply required some mechatronic knowledge and a PLC controller able to follow a magnetic line
- It might have been logical to presume robot vendors' expertise was primarily focused on creating the tool (top or front of vehicle, etc.) and organising the workflows
- As such, the core knowledge for these companies was primarily in how the solutions were put together
- Whilst AMRs using SLAM may have enabled a wider customer base for mobile robots, basics remained unchanged

WHERE IS THE VALUE?

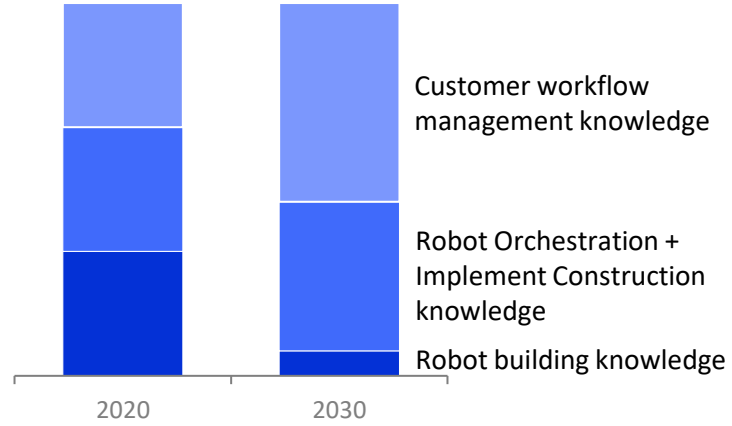
- One way of viewing mobile robots is they do not add value to payloads; their value is based on reducing costs from intralogistics and logistics processes

"Our company moves goods from one place to another and do not bring any value to the goods. This is the main difference between mobile robots and industrial robots, which is screwing, welding, soldering and so on. We are not giving value to the product, we are just moving product from one side to the other side." [Kivnon]

- The primary value add may be vendor's knowledge how to improve customer's workflows
- This was also reflected in some of the component vendor's developments

"One of the challenges we hear from the AMR solution providers is how to improve the ROI. Most AMRs deployed in factories and warehouses are restricted to operate in specific sections, making it hard to optimize the complete workflow. Also, due to the need for QR codes for localization and constraints on the design of the facility and traffic, many AMRs in the market cannot be deployed in brownfield facilities. With the Orin Nova platform, our goal is to provide the sensor, compute and development tools for ISVs and OEMs to develop more capable robots that can freely move in the entire facility, while spending list time and money on R&D. This will help to improve the ROI substantially and enable penetration of AMRs in more complex environments." [Nvidia]

CORE AGV & AMR VENDOR KNOWLEDGE BASE, 2020 vs 2030 (ILLUSTRATIVE)



Source: STIQ Ltd Research & Analysis

FUTURE KNOWLEDGE? A STIQ HYPOTHESIS

- Building robots may be commoditized in a not too distant future
- Constructing or designing implements (goes on top of a mouse vehicle, for example) alongside orchestration will remain equally or slightly more important
- Key future knowledge for AGV & AMR vendors will be to analyse, identify processes suitable for automation and how to improve workflows using mobile robots
- This may force a gradual evolution of the sector from mobile robot manufacturers to system integrators

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THE AGV & AMR ROBOTICS SECTOR LACKS SPECIALISTMOBILE ROBOT SYSTEM INTEGRATORS. POSSIBLY DUE TO LACK OF SIZEABLE PROJECTS

A NEW SYSTEM INTEGRATOR REQUIRED?

- STIQ interviews and analysis of the AGV & AMR Robotics sector has highlighted the lack of a system integrator layer specifically working with mobile robots
- STIQs view is that this is partly holding back faster market growth
- Whilst there were plenty of mobile robot distributors, these rarely have the know-how or expertise to sell larger solutions
- Local distributors and system integrators may also struggle to manage international customers
- Interviews have highlighted that the normal way of working with customers is via a direct channel

"I was with an AMR vendor for over three years. Once I was on board for a little while, I saw a need for integration partners that can help us scale. Distributors are good at selling 1-2-3 robots but when you start getting into the fleet software and managing those connections and the whole project management part of it is a challenge for many distributors. I put together a system integrator plan for the vendor and that's kind of what they've actually rolled out globally and Robex was one of the first to get on board." [Robex]

SYSTEM INTEGRATION LAYERS IN ROBOT SECTORS

	SMALLER PROJECTS	LARGER PROJECTS
Industrial Robots	System Integrator	System Integrator
Warehouse Automation	Often direct with vendor	Often with System Integrator
AGV & AMR Robotics	Direct with vendor	Direct with vendor (solution provider)

Source: STIQ Research & Analysis

WAREHOUSE OR FACTORY FOCUS?

- Part of the challenge for a mobile robot system integrator was the wide variety of work in warehouses versus factories
- This may lead some to focus entirely on one or the other

"We typically own the whole process in warehouses but we usually only own part of the process in factories. This is the main difference between production and storage or warehouse applications." [Synaos]

- Conversations with industrial robot system integrators have suggested there is not a lot of interest in mobile robots, possibly because projects could be smaller

"When I came onboard we tried to figure out how do we have a robotic arm systems group and then a mobile robotics group. That that's kind of what we're in the midst of planning now." [Robex]

- However, there were early signals things may be changing

"I think an industrial robot and a mobile robot project are very different from a project management perspective. You can quite easily define what success looks like for a palletizer. You know 95% uptime and hitting a certain rate, etc. You can define those things and lay those out. For mobile robots it's driven by the environment and that there's a pallet ready to be picked, that there's no pallets on the floor blocking paths and that nobody hits a mobile robot with a forklift… which happened last week. So you know it's a lot more variables that come into play. So from a project management perspective you got to keep your mind open with a mobile robot project." [Robex]

- STIQ also noticed a few mobile robot system integrators at various trade shows
- There was some evidence to suggest AGV & AMR Robotics vendors with international parent organisations or those with a more international profile, were partially pivoting towards system integrators

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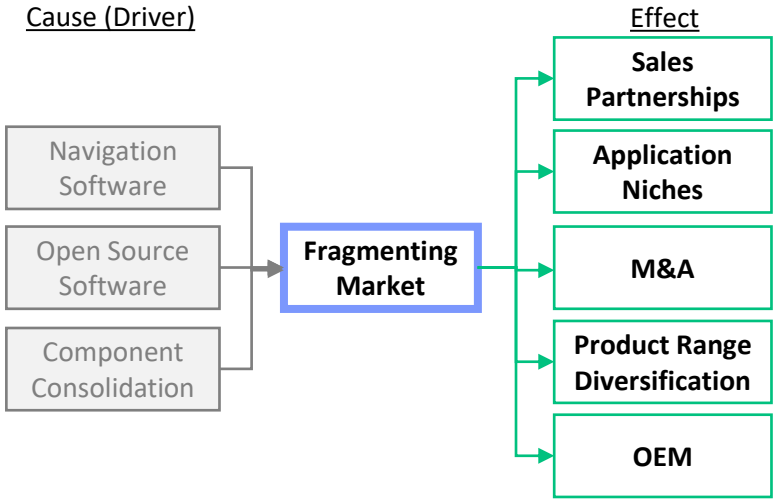
SIDE EFFECTS OF INCREASED SECTOR FRAGMENTATION

INCREASING FRAGMENTATION, CAUSES & EFFECTS



Source: STIQ Research & Analysis. Not an exhaustive overview

EFFECTS OF INCREASED FRAGMENTATION

- There were a few discernible trends in the AGV & AMR sector in 2022 partially caused by higher fragmentation
- **Increased partnerships**: More vendors have partnered with resellers and larger organisations, often SIs, to gain geographic coverage. Partnerships also included Joint Ventures and other formats
- **Application niches**: Increased competition in the core AGV & AMR sector has meant some vendors find more traction in adjacent segments and sectors. For example, a few navigation software vendors have focused on cleaning robots whilst some AGV & AMR vendors have focused on healthcare
- **M&A**: There were primarily two kinds of sellers in the AGV & AMR sector. Those with a slow growth legacy business, and startups about to run out of cash
- **Product range diversification**: AGV & AMR vendors fall on a greyscale of having a single product to multiple different products. There has been a recent trend of broadening product ranges pushing outside core businesses
- **OEM**: An increasing number of Chinese vendors began offering OEM during the pandemic. Some of these vendors switched to own brand developments

GROWING NUMBER OF PARTNERSHIPS

- Partnerships are not new to the AGV & AMR sector but appeared to have reached new proportions in 2022

"Our strategy is to gain a more balanced set up across more industries. We are starting to push into partner business to do projects together with a big integrator. There are more partnerships to come. It's either market or industry based partnerships. Our growth is not going to be only dependent on our own sales team, but it's also helping others integrate that type of solution probably under their label." [Safelog]

"We cooperate with AGV & AMR partners. We are not a robotics company, we do factory automation, machinery production, welding or screwing…factory equipment in general and provide integrators with material components, subsystems and knowhow…" [Bosch Rexroth]

- Joint Ventures were also increasingly common

"About two years ago, ADLINK & FOXCONN founded this strategic venture to create a new kind of robot, a new offering. FOXCONN is, and has been, more and more involved in the robotic field. They've been manufacturing robots for different companies out there… On the ADLINK side, they have been working on a controller called the ROS Cube, for the past six years." [FARobot]

CONSOLIDATION IN PARTS OF THE MARKET

- Some level of sector consolidation is expected as the market comes off high growth levels

"I think there's a fair bit of saturation in the market. At Modex in 2019 there were very few robot companies. In 2022 it seemed like everybody had a robot. There's bound to be some pullback in the market as some of the lower performers disappear and there is consolidation in the market… some companies are going to be consolidated by the wayside and some will consolidate upwards and grow. The industry was extremely, extremely hot." [Addverb]

"There's a little consolidation going on right now, but it's not a real consolidation. This will only be temporary because the market for automation will continue to expand for many years to come. We still think hyper growth within AMR is still a few years out. Of course, we think we are in the front of developing the most mature products, but if we compare ourselves to the forklifts sector, then we're still behind." [MIR]

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KEY AGV & AMR SECTOR TRENDS 2022

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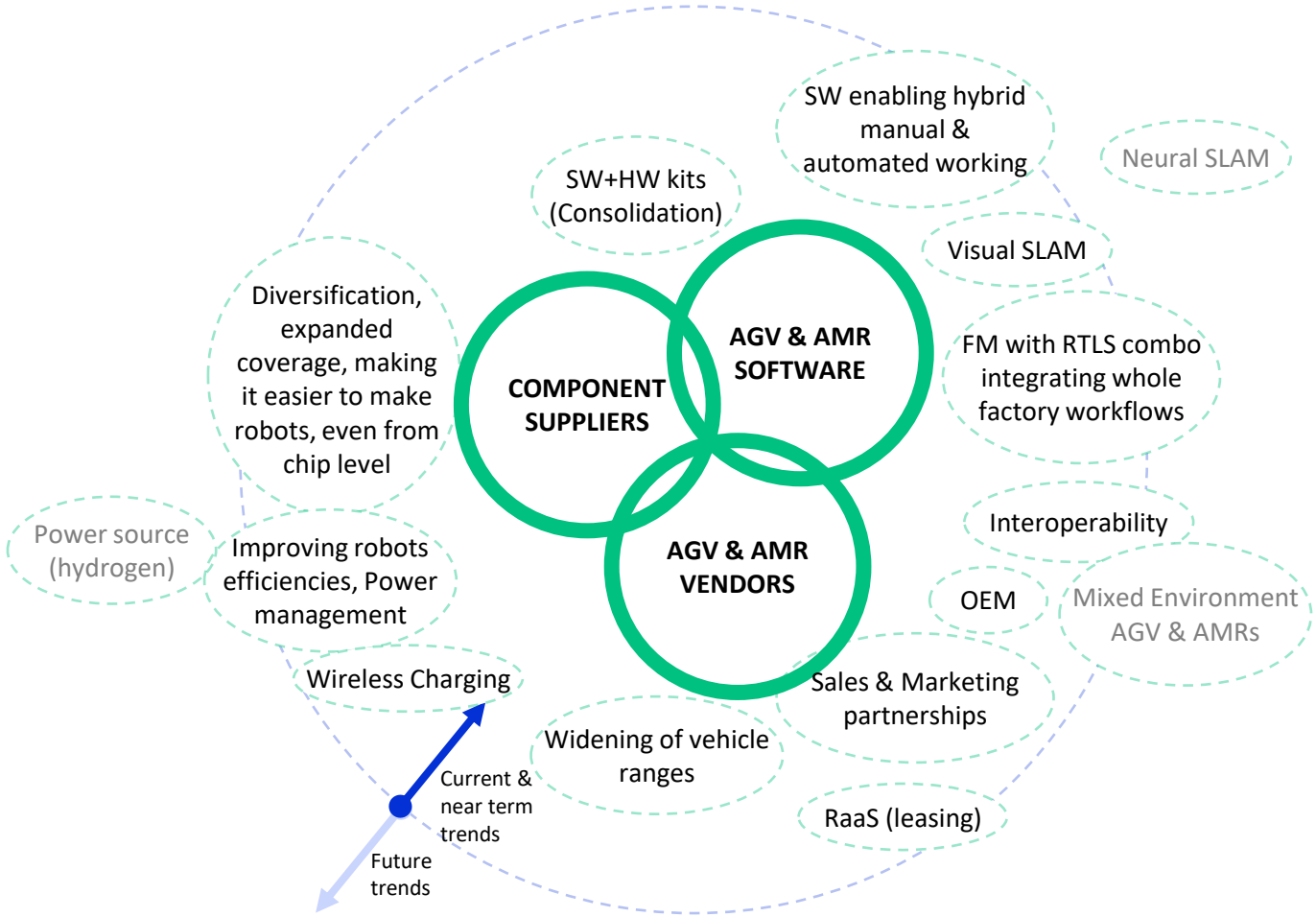
AGV & AMR TRENDS AND EARLY SIGNALS (NOT EXHAUSTIVE)



Source: STIQ Ltd Research & Analysis

KEY SECTOR TRENDS: DEFINITION

- A trend was defined by the number of times it was mentioned or alluded to in STIQs stakeholder interviews for this report
- Key trends were curated based on STIQs market knowledge and were representative of the overall AGV & AMR market rather than individual companies
- Note this chart should also be viewed in context of the many different business models in the AGV & AMR sector
- For clarification – please reach out to STIQ (see 1st page)

TOP TREND: COMPONENT CONSOLIDATION

- A major trend in the last 2-3 years has been component consolidation
- This means component suppliers are increasingly adding value to their components by bundling in hard or software to make it easier to build mobile robots

"While today every AMR developers starts from scratch choosing the sensor, computer, motors, software framework etc., we believe that many pieces of the AMR can be standardized. We are building Nova Orin to provide a common platform that can be used for all indoor AMR environments such as factories, warehouses, offices, hospitals and retail stores." [Nvidia]

- STIQs analysis was that these initiatives were meant to encourage faster market growth and are a way to capture a larger share of a market set to commoditise

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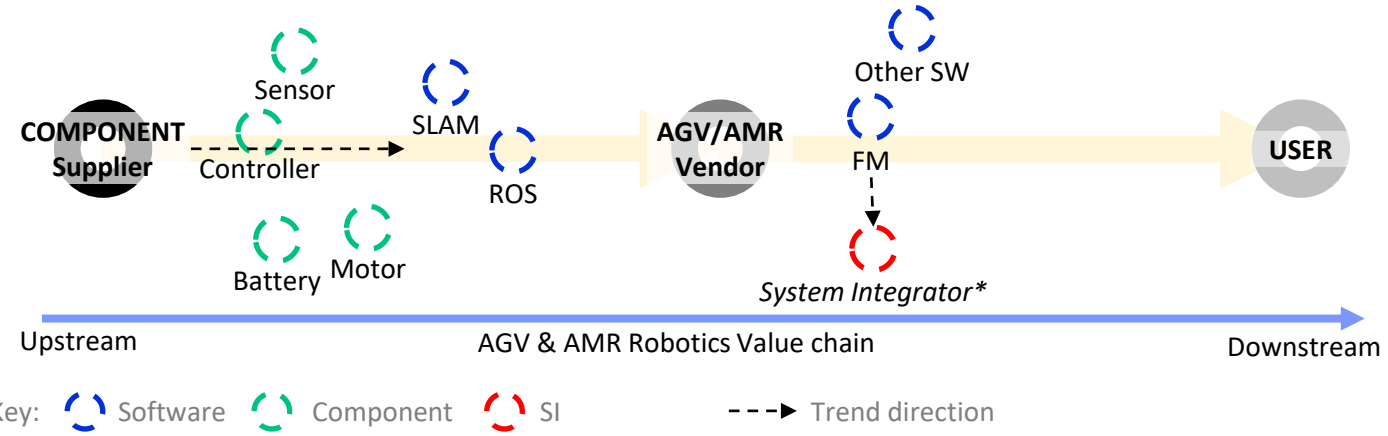
DOWNSTREAM CONSOLIDATION OF HARDWARE & SOFTWARE FURTHER REMOVING BARRIERS TO ENTRY

SIMPLIFIED AGV & AMR ROBOTICS VALUE CHAIN ILLUSTRATION



Source: STIQ Research & Analysis

COMPONENT CONSOLIDATION

- A range of component suppliers have consolidated hardware components and software bundles
- The primary strategic objective appeared to be to encourage faster market growth

"We definitely think Nova Orin will enable people to build AMRs faster because time to market is also important." [Nvidia]

"Our current localization software is a good base for further navigation and fleet intelligence development." [SICK]

"Over the last two years we have been incubating a separate business. We call it Matter X, but externally you can call it an AMR business unit where we're taking a sensor and then we can integrate a SLAM solution and essentially software solution to help localize the indoor robot." [LS LiDAR]

- STIQs impression of such downstream strategy was also to grab a larger share of a growing market

"We started with the Lidar with the localization piece. The SLAM is a box that sits either next to the Lidar or beneath it. So that's a module we can sell to customers and that takes us a little bit closer downstream with a bit more value to offer…

… And then with that we started working with different OEMs of forklifts and now we have several partners. A few in China, a few are overseas brands. So we're taking their vehicle and integrating our full set of solutions plus the platform software… the WMS. So we have that going on now domestically in China." [LS LiDAR]

COMPONENT CONSOLIDATION, NOT NEW

- Navigation Software vendors, in particular, have historically also offered hardware bundles to make the AGV & AMR journey smoother for customers

"Our business is to give our partners the possibility to purchase everything you need to automate a vehicle. So it's hardware, it's software… I mean the tools that you need to do an installation, the software and to have the system or the fleet management going and then the vehicle software and navigation." [Kollmorgen]

- The hardware component of these bundles has been core to stable functionality of the navigation stack

"We also produce and deliver a controller really just to guarantee quality. Because if you have a software that you put into a known, then performance is guaranteed. So we just launched the new generation with a performance that is guaranteed for the next 10 years. It's an industrial argument not commercial. We have done this from the start." [BlueBotics]

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A PRIMARY DRIVER FOR COMPONENT CONSOLIDATION HAS BEEN THE COMPONENT SELECTION AND CONFIGURATION PROCESS

COMPONENT SELECTION OFTEN ARDUOUS

- Downstream product consolidation focused on making life easier for AMR manufacturers

"We see that our customers are often spending a lot of time and money on re-inventing the wheel. Designing the right computer with enough compute and all the high-speed interface for the different sensors, choosing the sensors and calibrating them, developing a secure way to monitor and update your devices are few of the things that we have addressed for our customers in the recently announced Nova Orin platform. Combine this with a complete simulation model in Omniverse, designing AMRs is going to be much easier and faster." [Nvidia]

- The market appeared to appreciate such developments as there was a sea of components to chose from, and compatibility can be an issue

"We see this also coming, that AGV vendors wants the motor together with the controller… in the best case as a package. Then they can fully integrate this in the AGV. And we also integrate the controller in our wheel hub drives so that the customer can take the whole system from the AGV motor with the controller and integrate it very easily." [Ketterer]

- There were many different set ups among component vendors, some of which also provided AMRs

"We have two main business areas. The first one being the controller business, which is the fastest growing and most profitable. The second one is standard mobile robot business. We're focused on industrial applications and we don't really put a lot of efforts into e-commerce applications like QR code robots and so on." [SEER]

OEM IS ALSO PART OF CONSOLIDATION

- Some Chinese vendors have an integrated approach

"The Chinese market is big and very attractive. There are a lot of players. Early manufacturers of AGVs started by producing AGV controllers. And when they made the shift to manufacturers of entire vehicles and had to face the end users in the process of implementation, they found it difficult to complete jobs because actually, they didn't have the capability of giving a good service in the software management. Some of them decided to go backward and do OEM for AGV integrators. But for us, the target of the future, or to be the manufacturer of Aiten AMR and supplier of software, has never been changed." [Aiten Popifyindustrial]

"So, from 2020, 80% of the company's resources were dedicated in the development of our own brand which is Aiten and only 20% of went to OEM. And apart from that our OEM clients are all the international big brands." [Aiten Popifyindustrial]

UPSTREAM VALUE CAPTURE

- Interviews indicated some AGV & AMR vendors were moving upstream to capture more of the value chain and avoid some of the associated supply chain issues

"We now have a director of system architecture who is now heading our R&D for fully integrated circuit (IC) boards. So these IC boards we can produce on demand. Of course you need components, but even there we can swap components. This makes us less supplier dependent." [Addverb]

BROADENING OF THE SALES OFFERING

- Vendors are increasingly keen to offer their complete and/or relevant product ranges in solutions rather than focusing on selling a few robots

"Our focus is the flexible manufacturing concept. We are promoting solutions instead of just products since Omron is not only a robotics company but an industrial automation provider with the possibility to supply the whole solution. Last year we started a roadshow by different countries in Europe that we call Flexible Manufacturing Roadshow, this year we are continuing this activity in more countries. Then, business model of this year is a continuation of what we started last one, by promoting the concept flexible manufacturing factory instead of just mobile robots." [Omron]

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FLEET MANAGEMENT SOFTWARE HAS PIVOTED INTO WAREHOUSE EXECUTION SYSTEMS (WES) OR INTRALOGISTICS EXECUTION SYSTEMS (IES)

FROM FLEET MANAGER TO INTRALOGISTICS EXECUTION SYSTEM

Vendor Fleet Manager

Fleet Manager is used to manage AGV & AMR traffic

Agnostic Fleet Manager

Agnostic Fleet Manager is used to manage AGV & AMR traffic from many different vendors (interoperability standards developed for this use case)

Execution Solution

Intralogistics execution system used to combine all assets including AGV & AMRs, manual workers, manual forklifts, etc. into a flow. Including RTLS for manual vehicles/people

Source: STIQ Research & Analysis

INTRALOGISTICS EXECUTION SYSTEM

- A few Agnostic Fleet Manager vendors have pivoted into providers of intralogistics execution systems (IES) or warehouse execution systems (WES)

"Our solution is a tool for the responsible person to use every day because the factory is changing. If a machine is moving just a few centimetres it can influence everything, it can destroy the whole material flow. And you need to get the data, analyse the data and then you have to optimize it as soon as possible before some real intralogistics level problem appears." [NAiSE]

"We are building an intralogistics management platform. In intralogistics, it's all about interoperability between AGVs and AMRs as well as forklifts, other assets, and people on the shopfloor. This is our vision for centrally managing both automated and manual work processes." [Synaos]

"Vendors have a fleet manager and the vehicle controller element. We have a WES and PLC. By combining PLC with a FM you can send a robot somewhere, turn on the light to indicate what you need to pick and how to distribute it across the actual vehicle." [Guidance Automation]

RTLS USED FOR ASSET TRACKING

- Asset localisation (RTLS) has been an important addition to evolving agnostic Fleet Managers
- Part of this includes tracking and managing important assets that may interact or interfere with workflows, including people, manual vehicles, etc.

"We have our sensor kit which we can retrofit within half an hour to any manual forklift. The setup is pretty easy. It requires a power supply and connectivity to the wireless network of the facility. And then you have your RTLS functionality." [Synaos]

"Our RTLS is based on UWB with the clear focus to use it for this kind of scenario, we use it for traffic management in intralogistics." [NAiSE]

"Interestingly we also do have a lot of inquiries about tracking manual forklifts or manual like vehicles in the warehouse or production facility. Like RTLS." [Kudan]

"We received this requirement for tracking manual forklifts because they can cause expensive crashes. What we do is order distribution from top to down. So you have all the orders in a basket and then you distribute them across the fleet which contains not only various automated vehicles but also manual devices and for that purpose you need to know where the vehicles are." [Waku Robotics]

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OTHER KEY AGV & AMR SECTOR TRENDS 2022

SENSOR FUSION & NEURAL SLAM

- 3D slam is increasingly common in the sector and its future successor may be “Neural SLAM”
- However, conversations indicated this remained at a very early development phase

“Sensor fusion is complex. AMRs have multiple sensors… an average AMR has got 4-6 cameras, maybe 2 Lidars, a radar, IMU, and so on. You have to fuse all the information together at the exact time frames to create a map. That requires a different kind of compute, and sensor fusion was built around classical algorithms, but one thing that we're starting to see now is deep learning is starting to get good at the sensor fusion task as well. So this is one workload called Neural SLAM.” [Lemurian Labs]

- Sensors were key for mobile robots to experience their surroundings and there were signs vendors were using a wider range of sensor fusion mix

“Lidar systems have issues with detecting objects which are close to the floor reliably because there's typically just too much interference. Floor based object detection is where the Toposens technology is very good at detecting. Ultrasonic sensor technology is great at detecting small objects such as forklift forks as well.” [Toposens]

“In the AMR segment we can often solve the gaps SLAM still struggles with, like busy or open areas, ramps, and accurate docking.” [Accerion]

INDUCTIVE CHARGING, NEW CONCEPTS

- There were some new developments in wireless inductive charging

“We are building a new combined solution which is a 10-to-100-meter track which the AGV go to … and then it would keep feeding or charging for the length of the track. Instead of stopping on a specific pad, it could stop anywhere on the inductive track, or slide against it. It means several AGVs & AMRs can move behind each other and charge, maybe not at full speeds but they keep moving and go back to their processes.” [Conductix-Wampfler]

- Wireless charging is typically requested by end-users rather than OEMs

“Wireless charging is often a request that comes not from the OEMs, but from the end users.” [Conductix-Wampfler]

- Hydrogen power was a potential power source

“The automotive industry is changing… alternative fuels and all the stuff that is going on. In 2017 we decided to explore hydrogen… As a part of this we came in contact with the BMW plant in Leipzig and they asked us if we could build up a prototype for running their AGVs on hydrogen… The strategy is to convert the plant completely to hydrogen, including AGVs.” [FES AES]

VENDOR FOCUS ON RELIABILITY, STABILITY

- Some vendors have gone the opposite direction to adding new technologies and are focused on creating reliability, scalability and stability

“At least for now we're not implementing a lot of advanced technology into our road map. We’re focused on reliability, stability, cost. And that's on a 2-3 year roadmap. This is the shift we're seeing, going from a nice cool product that a lot of R&D guys like into a production facility where you have to meet takt times and where downtime means money. Then the requirements are more on reliability and stability of the product. Both hardware and software wise… But there's a lot of growth to come, so there will still be a lot of room for startups and new technologies.” [MIR]

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SUPPLY CHAIN ISSUES HAVE CONTINUED TO IMPACT THE MARKET SINCE 2021. LIKELY TO LINGER WELL INTO 2023 AND POTENTIALLY INTO 2024 FOR SOME SUPPLIERS

SUPPLY CHAIN ISSUES: PERFECT STORM?

- Chip shortages continued to be a key cause of disruption in the AGV & AMR supply chain with top component vendors also affected

"Last year at this period, we already experienced some shortages of specific semiconductors. Now it is very similar to the situation in other automation industries, where the supply chain is strongly influenced by souring standard components on a very limited base and with a tremendous price increase for parts, shipments, and utilities... Nowadays, there are probably some sub-suppliers which are not so strongly impacted by current sourcing problems... but we would say that most of the well know sensor and control providers are facing similar issues." [SICK]

- Disruption already experienced in 2021 appeared to have worsened in 2022

"One vendor did not even give a delivery date for some of their components. You place your order and you wait. You don't know when it's delivered… It's incredible that they don't know themselves. But of course, their supply chain is also very complex with many different suppliers." [Anonymous]

- Disruption tended to be across many different parts and components

"Most of the components affected are electrical, so PLC, lasers, navigation lasers… everything related to the electrical parts and their different issues, in terms of delivery lead times." [System Logistics]

SUPPLY CHAIN DISRUPTION IMPACTS

1. **Longer lead times**
2. **Unpredictability**
3. **Increased prices**

Source: STIQ Ltd Research & Analysis

UNPREDICTABLE LEAD TIMES

- Interviews suggested forward planning had become near impossible due to the supply chain issues

"In terms of planning it is a real nightmare now. So we had 2020 and things were a bit difficult. Then in 2021 we went up and set a new record. So fine. We normally ask our customers what growth they expect. But that was then and of course no one could imagine that we would have the Ukraine war. And yes this is unfortunately again worse for the supply chain. We ordered some components last week which were confirmed for January 2024. Planning anything is not easy." [BlueBotics]

"Before giving a delivery date to our customers, we ask our technical and purchase department to let us know the lead time for the components. We use this and add a security margin of let's say 20% more, but recently, even with this security margin we don't get components in time." [Anonymous]

"The problem is that sometimes it's very difficult to commit on a delivery date. Customers might ask, I'm going to order 20 robots, when will you be able to deliver them? Today we can say in three months, but most likely this will be different in a few weeks time. Component lead times are very unpredictable." [Omron]

- Vendors quoted lead times to customers when signing contracts and delays could cause financial penalties

"Supply chain disruptions is affecting us and we had almost +50% on our average delivery time. It affected the planning and forecasting and our offering stage. It also has an impact on what we can supply because most of the time delivery times are not met. So then we have to manage changes to the delivery schedule and obligations and maybe liquidated damages." [Anonymous]

- Vendors were between a rock and a hard place with their planning, if they over-estimated, they could be saddled with a large stock of components
- On the other hand, if they under-estimated they could potentially not meet demand

"Supply chain interruption is one thing. What I heard from the market is that vendors need to order all components for the next two years. They all have the same problem of forecasting, and they can only deliver what they're forecasting. So there's a shortage, but on the other hand, there's also a possible recession around the corner, a big unknown and how that impacts the market. So certainly… less demand for automation" [Waku Robotics]

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BACKLOGS APPEARED TO BE GROWING AS A RESULT OF SUPPLY CHAIN DISRUPTION. SIGNIFICANT MARKET IMPACT IN 2022

DELIVERY PROMISES NEAR IMPOSSIBLE

- AGV & AMR vendors suggested sales were good but raised concerns about timely deliveries

"We have a perfect sales funnel. So in terms of sales we will reach our goal. But we don't know if we can ship all those products by the end." [Agilox]

"It's a tough year to deliver. It's easier to sell, but it's not easy to deliver. Order intake is really positive this year. It was positive last year as well, but it's really positive this year." [Safelog]

- Navigation software vendors, often one customer removed, concurred

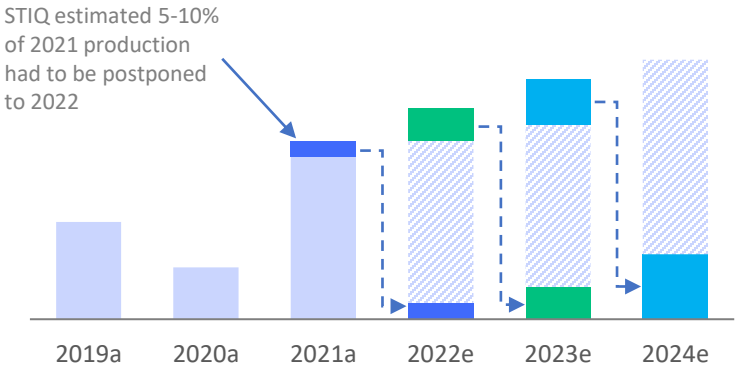
"In reality, unfortunately, some big names are struggling but it's mainly about supply chain… indeed we have no evidence of customers that say we don't have orders. Well, we have a lot of evidence of customers that are struggling to deliver right now." [Anonymous]

EVERYONE AFFECTED, A SILVER LINING?

- In a broader sense, there was a silver lining in that disruptions affected everyone

"I would say that the one that is most disruptive to us is company X's components, so specifically that brand rather than supply chain issues in general. But it just happens to be something that everybody is using. And their lead times are horrible, basically… The only silver lining is it affected everybody." [Geek+]

HYPOTHETICAL DELAYED PRODUCTION, 2021a-2024e



Source: STIQ Ltd Research & Analysis
Note: Not to scale, only to illustrate potential backlogs driving future demand

BUILD TIMES ARE INCREASINGLY DELAYED

- Many AGV & AMR vendors experienced extended build lead

"Perhaps two months was the standard time to build an AMR. Maybe now it's more like four months." [ForwardX]

- Some vendors were saddled with robots that lacked 1-2 components (and could not be delivered)

"Lead time for some components is more like 180 days now and this is quite complicated… in fact sometimes we have the AGV finished but we don't have enough components from some component suppliers to finish the AGV." [DTA]

SOME VENDORS TURNING AWAY BUSINESS

- Some vendors indicated they had to turn down business due to an inability to meet or to accurately estimate delivery times

"We probably have had to say no to a lot of stuff because we just couldn't meet the expectation on lead time." [Anonymous]

BACKLOGS BUILDING UP

- A side effect has been growing backlogs

"We had very, very bad lead times from some of our suppliers. So we were not able to deliver what we wanted to and we now have a backlog and we will not close it by the end of the year. Unfortunately we will deliver less than we planned. Everybody knows it. We are pushing, so we are suffering less today, but we still have some difficulties." [Anonymous]

- Some vendors were lucky in the initial part of supply chain disruption but found they depleted their own stock fast

"Our backlog was steadily growing throughout 2021-2022. The negative part is that no one was working during the supply chain shortage, so we have all these orders and are now trying to complete them. It depleted our component inventory." [Muratec]

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SUPPLY CHAIN DISRUPTION LIKELY TO CONTINUE WELL INTO 2023

SUPPLIERS WORKING HARD TO IMPROVE

- Component vendors were aware of disruption problems, but also struggled with their own supply chains, and in some cases these were very complex

"Of course, we realize that many customers are in a difficult situation if the delivery situation is not as it happened over past years, but we are doing our very best to expand our production capacities wherever it can contribute to this. To overcome the current issues due to shortages of critical components various optimization activities are in place now (e.g. alternative sourcing channels as well as redesigns on hardware) to improve the overall throughput to meet the increased demands of our customers." [SICK]

- Interviews suggested there may not be much improvement in 2023 and if there is an improvement it may be combined with higher prices

"Honestly, I don't think a lot will change in 2023. Maybe components or material will be available but at higher prices. That's perhaps the next challenge for the sector as a whole." [Ketterer]

COMPONENT LEAD TIMES (ILLUSTRATIVE), 2021-2023

	2021a	2022a	2023e	2024e
Component delays	↘	↓	↘	→

Source: STIQ Ltd Research & Analysis. Based on qualitative interviews and opinions.
↓=bad

VENDORS ARE HOPEFUL, BUT ALSO REALISTIC

- There was some level of optimism among AGV & AMR vendors

"In general, the second-half of 2023… at least I hope things will get better. We have been in this situation for the last year and a half. Some things are improving. But on the other hand if we talk about basic components, some of those are getting very hard to get. We are facing significant lead times. From what we're hearing from OEM's, things will not continue to be like this... But I don't think anybody knows for sure. I think it's like speculating what the stock market will be. It's just speculation." [Anonymous]

"The supply chain will be a little bit of a challenge for this year. We already got the CE certificate but from the supply chain news we heard some related parts that will have a shortage." [IPLUSMOBOT]

PRICE INCREASES IN TOW

- STIQ interviews in 2021 already indicated higher prices for some components
- Some of this has continued and been exacerbated in 2022

"So a little bit of delay, a little bit of increased prices, a little bit of not knowing when we get components. So we had a little bit of everything." [Sherpa]

- Supply chain pressures also attracted brokers and prices may have increased even more as a result of middlemen stepping into a "hot sector"
- This appeared to have accentuated some of the price increases

"Prices increased and some people were playing in the middle offering products at a higher price. This is this is the second part. But the first part is there were no parts available, nothing. So not even a question of price. I mean if there are no parts available, what should you do?" [Anonymous]

"In general, the market has gone from a really high push towards automation to a lack of components and ability to supply… But not so much for us. I think the worst we had was like 8 weeks of delivery time. So supply and availability of components is back to normal, but of course the prices have taken a step up." [MIR]

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NO SIGNS OF PANIC BUYING, BUT CERTAINLY A LEVEL OF SAFETY MARGIN AND BUFFERING IN COMPONENT PROCUREMENT

COMPONENTS IN STOCK

- Whilst there was no panic buying, purchasing behaviour certainly mimicked Covid buying

"This is also similar to the toilet paper situation during Covid. People are ordering extremely high quantities hoping to fulfill their customer orders for the next few years. So, some are probably ordering much more than they might need, which creates an additional problem on the supplier side, because if all ones are doing that in the same way..." [Anonymous]

- Interviews suggested some level of purchasing to keep in stock for longer than usual

"I'm aware that many customers are trying to buy a lot of components just to have them in stock." [Anonymous]

- Some vendors noticed supply chain disruption signals early on and quickly placed orders

"We don't have this kind of lead time because we trust in our market, so we placed open orders with our most important suppliers and have some stock sitting in our warehouse. But, even though we placed orders one year ago it was still not easy to get the parts." [iFollow]

- Whilst other vendors procured key components to enable them to meet ambitious growth targets

"Because lead times started extending, we changed our plans since we weren't going to get parts in time. We over ordered to make sure we had stock to smooth out our growth path over the rest of 2022 and 2023. We've now also got to that steady state with our forklift providers. Their lead times had absolutely blown out and lead times went from 2-3 months to literally two years in some cases. But we've now got that under control… steady beat in of machines." [Anonymous]

"We managed to stock up according to our prediction for next year… we should be covered unless we are extremely lucky with sales. We should manage to deliver according to the schedule for 2023." [Anonymous]

- Good forecasting may have alleviated some of the disruptions alongside some component buffering

"Our lead times have extended a bit, but we're not quite where some of the large SIs are where they take orders for 2025 now. We're still counting in single months for our lead times… We've done a pretty good job with forecasting and getting the parts we need and we did perhaps buffer a bit." [Vecna Robotics]

MULTINATIONAL PROCUREMENT ACTIVITIES

- Whilst it may have been easier for smaller vendors and/or startups to stock up, larger companies also attempted to stock up
- Larger companies actioned multi-continental procurement of some of the more hard-to-get standard components

"We have taken a risk to increase our stock of critical parts. We get them here and there… as a global company we have global actions on purchasing. So there are things we buy in Singapore, China, Canada or in France or wherever." [Alstef Group]

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THERE WAS A SENSE OF A SOMEWHAT HESITANT ACCEPTANCE OF THE NEW SUPPLY CHAIN STATUS QUO AMONG VENDORS

VENDORS USED TO DISRUPTION

- Supply chain issues began shortly after the first few Covid lockdowns and have now been prevalent for more than a year
- Some vendors appeared to have accepted a degree of disruption as the new status quo

"'I don't think we've seen an improvement since the first impact of the pandemic, moreso that we've all gotten used to the current state of affairs as the new normal." [Third Wave Automation]

"It's it is a fact of life these days. An unfortunate fact of life. Yes, we have become used to the new normal supply chain issues." [Addverb]

- Interviews indicated supply chain disruption had now been baked into project quotes

"We generally have a clear sightline on our deliverables from our supplier base so we can plan that into the project itself. It's a known part of the schedule. The supply chain delay is baked into our schedule. It's now fairly predictable and it's improving… the global commodities markets are improving." [Addverb]

- More recent entrants may have found themselves in the midst of supply chain disruption and experienced significant extra work to smooth out their supply base

"What was an issue was electronic & electric components starting from cables, connectors and also to system parts like controllers. We managed it well, but it slowed down our pre-series production a bit. We now have a stable supply base. But this was really challenging, so it caused unexpectedly a lot of extra effort in all directions. So the complete team including our R&D had this additional workload to qualify other sources or other components." [Continental]

SOFTWARE PUREPLAYERS ALSO IMPACTED

- Software vendors were indirectly affected by disruptions

"When you look at an AGV & AMR robotics project, there are many parts to it. If the end customer doesn't receive hardware because of supply chain issues, then there's also a delay for our project. So even as a software vendor, we can also be affected by this supply chain issue." [Synaos]

- Although some of these vendors were part of larger organisations and could leverage size in a few cases

"Our main business is software components so hardware disruption is not a direct impact to our business…of course we see also the projects of our customers being delayed, they do not get specific components. I think the supply chain issues will get resolved some time soon." [Bosch Rexroth]

"Zapi, our new owners have deep experience in production and supply chain. They add a lot of knowledge and experience in these uncertain times." [BlueBotics]

VERTICALLY INTEGRATED VENDORS

- A few vendors indicated their lead times were not very long partly due to their business models
- Some of these vendors were more vertically integrated

"We do feel a huge impact from supply chain disruption but we do have a fair amount of insulation in the fact that we have very strong relationships with our suppliers. We're also very vertically integrated with our own factory. This means that we don't rely on partners as much as some others. Our factory does everything. We take in raw sheet metal and component level electrical hardware... And we have our own PC fab with a surface mount line. We can do our own board fab together with our hardware side of the factory, we can build quite a bit of the robot without relying on another layer of supply chain which is very helpful." [Addverb]

"No, we don't have that long lead times. We don't have the issue of the customer cancelling our projects because of lead time, but actually that's you know one of our advantages compared to some global companies. [VisionNav]

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SOME VENDORS HAVE ATTEMPTED TO DESIGN OUT COMPONENTS

INCREASED USE OF OFF-THE-SHELF

- Interviews for the 2021 report indicated there had been an increased focus on using more standard & off-the-shelf products instead of bespoke products
- This appeared to have had a positive impact and offset some of the supply chain problems

"We try to have standard components that can be applied to different AGVs… We are not saying that we are not affected, but of course it's a good trade off because we have some components already both before the crisis. And we are trying to anticipate any issues, so try to see if we can have some alternatives available in the market." [System Logistics]

"We ran a general scalability initiative across the board as we're trying to ramp up manufacturing capacity. That's part of our best practice initiatives. We already got a fairly standard configuration across our trucks and uses the same components across vehicles… trying to keep things simple." [Vecna Robotics]

DESIGNING OUT COMPONENTS

- A few vendors embarked on different component strategies and redesigning initiatives to improve and make their supply chain more resilient

"Clearly we are going to debate redesigns to make our supply chain or products more agile. But like you know it's an improvement in design you are doing in order to be more flexible at the end in manufacturing. But the main issue of today that… If we do it today, we will apply it within six months to one year." [Anonymous]

- Some companies had deployed redesigns to reduce dependence on single component vendors

"We reduced our dependence on Company X rather than completely eliminating it. But if you can only get a few 1000 components per half year, then you can only sell a few 1000 robots. This is unacceptable to us." [Geek+]

SEEKING OUT SUPPLIER ALTERNATIVES

- Redesigns included working up supplier alternatives and multi-sourcing

"We are always on the lookout for equivalents and we always have an option to have at least 2-3 vendors for a component for almost all the main critical items. That's how we have been able to ride the wave. It's a hard wave to ride given the conditions that are around, but I think so far we've got the right mitigation strategy in place so that's putting us in a good position." [Addverb]

"We're always looking for improvements in our supply chain. I'm pretty sure that some competitors and their R&D departments are working hard to create replacements for components that are out of stock now. I know there's a supply chain shortage, but it will not last forever. I believe the supply chain issues will improve towards the end of 2023 & beginning of 2024." [Muratec]

"We've made some key components to be variable. The difference is that we are very, very conscious of COGS. That's why it's very inspiring to watch the Chinese companies work so hard to lower the component costs." [Avidbots]

BUT RE-DESIGNS MAY COMPLICATE SERVICE

- For others, new suppliers might complicate remote service & maintenance if the alternative is difficult to find and purchase in certain countries

"We make some tailor made solutions. But even if we make tailor made solutions, we are trying to standardize our components. That means we use the same components and if we begin to change all the kind components it becomes a mess… also for calculating the pricing." [DTA]

- And, if vendors are part of a wider value chain there may have been further delays to projects

"We have been always capable to deliver robots, just sometimes with slightly longer lead times even if there are constant issues with different suppliers, we can finally find alternatives to continue deliver mobile robots. But the real problem is that we can deliver our robot platform, but our customer has to work on the integration part and put something on top, like a conveyor, a lifter, or any other equipment to perform the job, this can include different products like PLCs, buttons, etc. In the end, even if the delivery time of the robot is just a bit longer, the whole project can be delayed due to other products." [Omron]

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COULD SUPPLY CHAIN ISSUES BOOST THE CREATION OF A 2ND HAND AGV & AMR MARKET? WILL RETROFITTING AND/OR SALVAGE ALSO BENEFIT?

A SECONDARY AGV & AMR MARKET?

- Interviews suggested there may be an opening for a 2nd hand AGV & AMR market

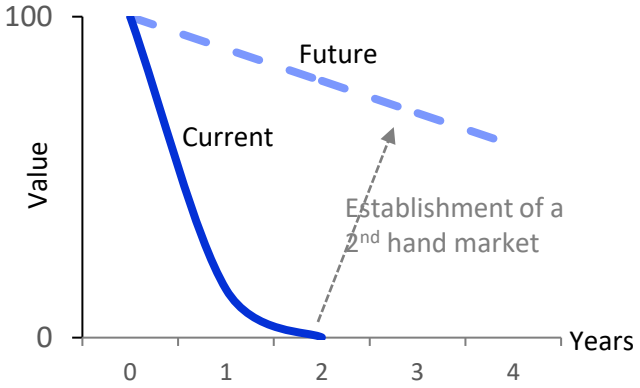
"Customers say we need automation, we need to move quickly. Some decisions are based on current needs, perhaps not needs in the next 5-6-7 years. Our approach is how can we be more sustainable in the approach? And sustainability in AGVs & AMRs means making sure that the products got a useful life beyond the initial phase and that's sometimes a challenge. It used to be really difficult, but it's becoming a bit easier now to transfer a solution to another application. The opportunity is how can we make a 2ndary market for AGVs & AMRs. Is that feasible? I think it is to a degree, but not on the same level as what forklift trucks are now. But in 5-10 years time the AGV & AMR marketplace will be different." [CHG Meridian]

- A secondary market for AGV & AMRs would not only add an interesting dynamic to the sector, but also allow financing companies insights into residual values

"I think that the marketplace will grow, which enables us then to add greater residual values into the assets because we understand what the value is after, you know, 3-4 or five years?" [CHG Meridian]

- This could ultimately assist with more attractive customer financing packages
- A secondary marketplace may be more interesting for some leasing finance providers depending on the type of lease provided

ILLUSTRATIVE RESIDUAL VALUE AGV & AMR



Source: STIQ Ltd Research & Analysis

"In the wider automation sector about 15-20% is leased to some degree. We don't offer a financial lease which gives the customer ownership at the end of it. We only work on residual value based leases." [CHG Meridian]

RETROFITTING, AN ALTERNATIVE TO NEW?

- Retrofitting AGVs & AMRs is not the norm, but does occur
- Current long component lead times plus inflation, has led some customers to chose retrofitting despite limited cost benefits
- However, a key benefit was time to deployment

"We have retrofitted an air cargo fleet also of 20 feet pallets airport pallets. These were installed 30 years ago. We retrofitted that. And I think that there is not a lot of people, I think there's only one other company doing that worldwide. These are huge AGVs and can transport more than 25tonnes… Instead of changing the AGVs they just brought them up to date. They do every change you would normally think. We changed computers, variators, etc. It comes to nearly the cost of an AGV and it's not often you do. But like that, they drop a bit of the investment and they keep them running. We also have customers which are … instead of changing everything at once, they're changing stepwise. So they change two this month and the other two a couple of months later." [Alstef Group]

- Retrofitting of existing vehicles appeared to occur across the globe

"We're focusing on SLAM localization research. In our 2nd year of development, we had some pretty good results and a customer requested our VSLAM solution but ultimately we retrofitted their AGV with our 2D Lidar solution as it was more stable. Many customers use another vendor's localization tech which is very expensive because it's an international company." [Techvico]

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INTEROPERABILITY MAY BE INEVITABLE. MAINLY REQUIRED BY AUTOMOTIVE SECTOR. ALTHOUGH OCCASIONALLY INCLUDED IN RFQs FROM OTHER INDUSTRIES

INTEROPERABILITY STANDARD INEVITABLE

- As the market for AGV & AMR Robots grow, there may be an increasing requirement for interoperability between different vendors

"Mobile robot producers don't want to commoditize their products by engaging in an open standard. It's like with industrial arms. You can control them all from anybody's PLC. There was a day when you were locked into vendor ecosystems. But there was enough push in the industry to say I need to be able to switch out these robots easily. Mobile robot producers don't want that, but I don't think we can shy away from this. It is the trend we've seen in other industries and in other technologies and that trend is going to happen in AGV & AMR as well." [Anonymous]

A MIXTURE OF STANDARDS MOST LIKELY

- There are currently a few standards in development with Interop and VDA5050 the most well known

"There are so many standards and I believe there won't be one standard… What I expect is that if you now buy an audio file, it could be an MP3, it could be MPEG, etc. So you have multiple standards. And I guess a fleet management system should be able to do the same, talking many different languages, even having connection to open API's or REST API's that the vendors could provide." [Waku Robotics]

VENDORS GETTING READY

- VDA5050 is increasingly included as a requirement in RFQs when working with German automotive vendors
- More recently it has also begun spreading into other sectors, primarily in Europe

"VDA 5050 is becoming much more requested… 18 months ago people started asking about whether we have that as a sort of a checklist item… about 6-12 months ago they start putting it into tenders. Now we are really seeing that, OK this has turned from something they want to know about to something that they actually put in as their purchase requirements. We are in the development of VDA 5050 and will roll it out with the next generation of products." [Geek+]

- Plenty of vendors were in the process of adding VDA5050

"We are in the process of adding VDA5050. We want to be collaborative either where we become the master FM or we are part of another FM. We want to be flexible either way because software is where our strength lies. Be it a connector for a FM, WES or the manufacturing execution layer. We are already used to integrating with a lot of non-Addverb products from day one… Our company was founded by automation users turned creators. So we were on the other side of the table when we started the company." [Addverb]

"We're on target, and I think we should be VDA 5050 compliant next year. It has been a big speaking point that I believe has been driven out of Germany. But it's getting a lot of traction within the US, and we have been receiving questions from customers on our road map for VDA 5050." [Muratec]

ALREADY ADDED

- A few vendors are VDA505 compliant from the start, especially German vendors that were part of developing the standard in the first place

"We are in the VDA 5050 consortium. Our master control and the software that we have on board of the robots, the brain we developed directly from the beginning with the VDA 5050 interface. So it was part of our system since we have launched internally in 2019." [Continental]

OTHER RELATED STANDARDS IN PROGRESS

- Other related standards have been released, such as Omlox (Profibus, link) for locating technologies (RTLS)

"Omlox is a locating standard that is not only for AGVs but also, for other moving things. System that are Omlox-certified can provide a standardized access to location data in 3D." [Flowcate]

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STANDARDISATION AIMS HAVE STRUGGLED WITH THE MANY DIFFERENT VARIATIONS IN THE MARKET, ESPECIALLY NAVIGATION TECHNOLOGIES AND HOW TO MANAGE MAPS

VDA5050 NOT PRODUCTION READY YET?

- Interviews have suggested interoperability standards remained at a nascent stage

"Some vehicles are made for VDA5050, like line-guided AGVs. Whereas VDA5050 is not the right standard for AMRs at the present time. They love VDA5050 and AMRs don't like VDA5050 and VDA5050 is pretty early on. It's not very specific in many cases and it's still in the making. To my knowledge, there's no installation that is running on VDA5050 in production right now. It is all working on a demo basis therefore it's not necessarily ready for production." [Waku Robotics]

TURNING ADVANCED AMRs INTO AGVs

- Top issues with VDA5050 include that it not only commoditizes robots but also reduces the autonomy in more advanced AMRs

"People should understand that under the current version of VDA5050, suddenly their AMR became an AGV. Because it's just following the static route, not anymore making autonomous decisions. We had a lot of discussions with different plants about, OK, there's always a reason why they use an AMR and not an AGV." [Anonymous]

- However, many vendors accepted interoperability is going to be important and that standards will hopefully evolve to manage the many different vehicles

"I think interoperability is going to be important and the industry is going to get to a point where we are all going to have to collectively rally around a standard, such as VDA 5050 which is not a good standard. It's not a standard built for autonomous robots. It's a standard built for AGVs." [Anonymous]

UPDATES IN VDA5050 BETTER FOR AMRs

- Updates to VDA5050 appear to be moving towards improving the functionality of AMRs

"We had some talks, very detailed talks with different vendors of VDA5050 software. We are talking with all the major providers and see a very interesting development here… And that was always our pain point that there was no smart solution for AMRs. But that's coming up now and it's going to be more interesting for us with this new VDA5050… We have a very close look at this and we are very aware of the fact that this will be a game changer in future and we invest quite a lot resources to monitor these trends." [Agilox]

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SOME CUSTOMER'S PRIORITIES APPEARED TO BE MORE ON INTEGRATION LAYERS. INTEROPERABILITY ONLY ONE OF MANY DIFFERENT PRIORITIES

CURRENT PRIORITIES ELSEWHERE THOUGH

- For many stakeholders, interoperability appeared to be further down the mobile robots priorities list

"A lot of people are working on interoperability of these systems, so different vendors can work together. I think that's probably still a little way out. I think the piece that we're missing right now is that middleware layer of just connecting robotic systems to WMSs." [Robex]

- Interoperability may be less relevant for solution vendors where a single vendor is exclusively used to support overall functionality with full control of own produced vehicles

"Customers in our sector are perhaps aware of VDA5050 but for now they prefer to have one single shop. Let's say they are not looking for different vendors, that's a different request. Our projects are solutions and there is no need to mix with other vendor's vehicles." [System Logistics]

- Furthermore, some customers STIQ interviewed had considered applications with different vendor's robots, but decided it would be too complex and focused on the main application

"We rather just look into covering certain use cases and not all. But cover those use cases just with one supplier. That that makes it easier. So this would be a really specific use case where we say yes, it definitely makes sense to combine vendors." [Anonymous 3PL]

- However, such buyer behaviour could also signal that vendors may enjoy a significant first mover advantage for future projects

CLEANING ROBOTS AND INTEROPERABILITY

- Cleaning robot vendors did not appear to have encountered any interoperability deployments

"Standards is something I don't think even the industry has made a final decision on yet. It's definitely in motion… and we are paying attention and trying to abide by the rules posed by our customers." [Avidbots]

- Interoperability may only be one issue and things like residual water from cleaning may be another

"We have not yet integrated cleaning and other robots. But we have had some requests. But, there are some potential problems… a cleaning robot can leave water on the ground. How is the performance of the logistic robot affected by this? Should we plan the cleaning in order to not interfere with logistics… it is probably the most logical way." [Proxima Robotics]

FM VENDORS ALSO VYING FOR TOP SPOT

- A few AGV & AMR vendors have attempted to become the gold fleet manager with many different robot companies attached to their system

"I think everybody wants us to plug in to them. We get these requests quite often. I will talk to one AGV & AMR company and they'll ask us to join them in their big thing with their fleet manager." [Avidbots]

- Some vendors may shy away from adopting VDA5050 as their value may be highly integrated to deploying their own robots exclusively

"There are some robot companies that probably won't adopt VDA 5050. One reason is that they have developed significant functionalities within their own fleet management software... operating without their own fleet management doesn't make sense." [Waku Robotics]

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CRITICAL SUCCESS FACTORS FOR AGV & AMR PROJECTS INCLUDES SENIOR MANAGEMENT BUY-IN

TOP KEY SUCCESS FACTORS FOR MEDIUM TO LARGE AUTOMATION PROJECTS

Success Factor	Description
Sr management buy-in	• Potential for significant positive impact on operations and appropriate budget allocation • Top down chain of command often makes projects smoother • Setting of project outcome KPIs
Customer knowledge	• Knowledge of suitable vendors (hugely fragmented market) to present suitable RFQ responses • Internal knowledge of processes to be impacted, changed and related software work • Outcome expectation management
Existing infrastructure	• Appointing project manager and possibly an assistant PM as back up • Allocating additional resources, such as IT, finance, change management teams, etc. • Post project handover/sign off set up

Source: STIQ Ltd Research & Analysis. Not an exhaustive list of Key Success Factors

SENIOR MANAGEMENT BUY-IN WAS CRITICAL

- Vendors emphasised that Sr management buy-in is critical for project success

"It's absolutely critical that projects are top down on the customer side. You can get somebody in a non-decision making position who can clearly see the benefits of automation because they're living it day-to-day. But without that individual really making a convincing case for the ROI with their senior management, the capital budgets just generally do not open up and it can become very frustrating for the operations team, for all involved when you try to solve that problem. So an understanding of the value at senior level is vital before discussions really proceed further." [Addverb]

- Larger automation projects were rarely simple and typically required customers to have some awareness of processes involved, software packages (ERP, WMS, etc.), suitable vendors, internal post-project management, etc.

"Senior management buy-in is critical. We spend countless hours working with engineers, warehouse managers, and the people who will engage and utilize the equipment daily. We think it's important to help them fully understand the capabilities and benefits to best prepare them for that conversation with leadership. So, we try not to sell a product and walk away but partner with the people we're engaging with." [Muratec]

"The most important success factor is knowledge on the customer side. As long as they're dependent on our know how alone it's going to be hard. They need a set up, a team, infrastructure, IT set up that's even possible to do a robot project. So the most important success factor is competence on the customer side." [Safelog]

POTENTIAL TO UNDERESTIMATE COMPLEXITY

- There is always potential for even the best laid plans to go wrong

"We worked with a client who did a lot of background research into the required automation operational flows. However, they underestimated the complexity of this sort of project, particularly around project management. There was a project manager on the job but he left halfway through. Other members of the team tried to step in whilst juggling their day-to-day job." [Hatmill]

- Software integration work can often add layers of complexity to gain expected outcomes

"The client was only getting 40% of throughput compared to what they had asked for. They underestimated the complications associated with the WMS, RCS, and ERP systems. I don't think they appreciated the complexity of integrating these systems and how they would communicate with each other." [Hatmill]

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SIGNS OF RAPIDLY INCREASING CUSTOMER AWARENESS OF AGV & AMR ROBOTICS IN NORTH AMERICA & EUROPE

INCREASING AGV & AMR AWARENESS

- Increasingly, potential customers have knowledge about mobile robots and also some of the limitations and possibilities of deployments

"It has happened that customers come to us lacking knowledge of their own workflow. But that is very rare these days. It is more, here's our process, here is what we do today and this is what we want for tomorrow. How can we work together?" [Alstef Group]

- Some companies appeared to have used lockdowns to educate themselves about AGV & AMR Robotics, intralogistics and more

"There were a lot of enterprises, especially the larger ones, who were spurred on by Covid-19 to really sit down and educate themselves about logistics, logistics automation, warehousing, and to set up a proper strategy. So, the awareness and maturity levels within the market really went up." [Synaos]

"The first part of the project is normally consultancy or education. Absolutely. A couple of years ago people came to us asking here's my problem, please tell me what you can do. But now people are coming oh, I have seen that on LinkedIn or YouTube and I want that. And then it's more about but this is maybe not what you need at the end of the day. So we have a little bit more of that. But at the end of the day customers understand a lot about flow or what do you need to transfer, what do you want to do with it?" [Alstef Group]

EDUCATIONAL PHASE REMAINS IMPORTANT

- However, partly due to the application range of mobile robots, variety of vehicles and options, the educational phase remains an important part

"We have seen that as well, the educational phase… not with all customers though. Our busiest person on staff is probably our sales engineer." [Third Wave Automation]

"Once people see how the robots move and how they interact with staff they see that robots are not scary. In a strange way it's a marketing exercise because managers in other departments see the robot moving and they come up with ideas of how they could utilize a robot somewhere. Once you've got that first small fleet moving around, not really interrupting current processes, just taking some of the walking out of the processes, then people are a little bit more open minded." [Guidance Automation]

- There is also a natural part involved of highlighting the various material handling options, and which may be more suitable for particular applications and businesses

"A lot of customers may first think they need a conveyor. But especially in a growth scenario, you can make quite a business case for an autonomous solution. Fixed solutions require long-term infrastructure planning and installation – let's say until 2025 or even beyond. AMRs on the other hand are a more flexible and scalable solution. I believe there is some potential that professionals don't automatically think of conveyors to move pallets but also have alternatives in mind such as AMRs to do the same job." [Körber Business Area Supply Chain]

CURIOSITY PIVOTS INTO BUSINESS IMPERATIVE

- Increasingly early curiosity of AGV & AMR robots has been largely replaced by more serious inquiries and operational efficiency drivers

"What I can see is that in previous years, customers would want to be educated about AMRs and understand them. They would look at them as an option. Since last year, however, customers deliberately come to us saying they've done their research, need AMRs and ask us for a proposal for their project. This has changed in terms of market maturity, education and in terms of business." [Körber Business Area Supply Chain]

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WHILSTS MANY CHINESE BUYERS APPEARED TO BE AGV & AMR NATIVES

CHINESE AUTOMATION BUYERS

- The Chinese domestic market for mobile robots is very large and buyers/potential buyers appeared to be near natives with AGV & AMR robots

"More and more Chinese customers have automation departments and a person from the integration industries. This person have more knowledge about the automation system. So factories have a certain person who can manage and who can use the AMR or other related automation equipment freely." [IPLUSMOBOT]

"Chinese end users already have a plan in place and they have a very good understanding of what AMRs can do. If we're being approached by an end user they rarely ask us AMR 1-0-1 questions. Usually they already have done their research. It's already well adopted here in China. So many times when our integrator works with the end user, they will be sitting down talking about workflows, pace, cycle times or trying to improve efficiencies and pushing the limits of AMRs instead of understanding the basics." [SEER]

- Part of this was due the continued rapid pace of new factory and warehouse construction in China, where new buildings often can incorporate mobile robots

"For a domestic Chinese project, in the past most of the AMR projects would be brownfield, retrofitted automation. But integrators have more and more knowledge about the AGV & AMR and also factory owners or the end users get the knowledge and the experiences of the using AMRs. So a lot of new factories will nowadays have the automation requirement beforehand, and be built for AGV & AMR robots and they will have the requirements built into the facility." [IPLUSMOBOT]

- Another factor is the pace and intensity of domestic competition in China which has led to a huge surge in the number of vendors

"It's not really that difficult to DIY an AMR when compared to a Lidar or a controller. If you graduated with a STEM background, find the right components supplier who have already figured out the brain, sensors and software, you could build an AMR in a week. So it's not that difficult really to build an AMR….. although building an AMR which is very reliable and economic is a much bigger challenge. I guess this reduced complexity has probably helped to drive the competition for AMRs. For the QR machines, because it's already so cheap, so not many suppliers are trying to get into that field. Here in China only for AMRs we have definitely 100+ players at least... I think we're probably talking about 160-200 players" [SEER]

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CONSULTING INCREASINGLY IMPORTANT AS PART OF PRE-SALES/ EDUCATIONAL INITATIVES

CONSULTING AS PART OF BUSINESS MODEL

- In many cases the AGV & AMR educational phase had been replaced or interchanged by a consultative approach, often highly appreciated by customers
- Interviews highlighted many customers welcomed the consultative approach

"I think we had a little bit of roboticist conceit of we're going to make a machine that you can drop in and it'll do everything without any infrastructure changes. But what we're finding is customers are actually very happy if you analyse their process flow and you come back with real evidence… if you do these three things, the process flow will be better. I don't know if it's just having another pair of eyes looking at it or just that we come from a different point of view. There's often some optimization available just by examining the system… we like to add our automation into it of course. But we also often give our customers just, hey, if you do these things, it might actually be better for you with or without." [Third Wave Automation]

- Pre-sales engagements can take many forms including iterations of the most suitable applications and projects

"I would say that the human part is still the most valuable part of this. We tend to spend upwards of 6 months in the pre-sales process. Talking through every detail of the project with the customer. And it's at that stage they are also talking to other people and there's ideas flying all over the place. We try to guide them with our experience and say, well, this is an amazing idea, but it's also going to be a whole lot of engineering and here's a much simpler way to achieve a better result and so on. There is a lot of value being created in the pre-sales process in terms of figuring out what is the optimal way. Quite often the starting point is you have an existing process and you have some limits on how much you want to change. But we really go in and analyse what is the right tools for the job and so on." [Geek+]

SOFTWARE VENDORS, CONSULTANTS

- Interviews indicated a trend among software vendors, especially those focusing on fleet manager functionality, often getting involved in more consultative projects
- This could partially be due to their often robot vendor agnostic approach
- Furthermore, many of these vendors were pivoting into WES (warehouse execution systems) functionality

"Many customers don't have the market overview and may not understand the technical possibilities of solving particular use cases. They have a good understanding of their processes but don't know how to automate them with specific applications. They might contact 2-3 vendors and if they say no, they believe it doesn't work. Oftentimes this uncertainty due to automation applies to companies that may already have implemented their first robot. And then, of course, have the huge segment of companies that do not yet have any experience with robots. They often don't know how to get started therefore they need individual guidance." [Waku Robotics]

- Early stage consultancy can also make potential projects smoother, easier to implement and deploy

"A recent change in our go-to-market plan has been to expand our upstream offering to include early-stage project and consulting work. While this isn't the core of our business, we have found that project implementations run faster and smoother the earlier we get involved. Enabling clients early on really helps accelerate the rollout of the project in subsequent stages." [Synaos]

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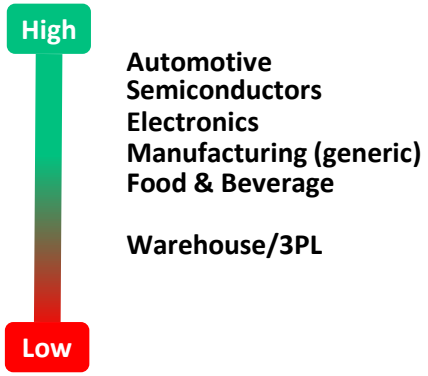
AGV & AMR ROBOT PROJECTS EXPERIENCE VARIED BY CUSTOMER INDUSTRY SECTOR

"AUTOMATION READINESS" BY INDUSTRY SECTOR



Source: STIQ Research & Analysis. Not an exhaustive list

EXPERIENCE BY INDUSTRY SECTOR VARIED

- Some sectors were more adept at managing automation projects, such as automotive, electronics, etc.

"It depends on the customer to be fair. Some sectors like automotive has always been well versed in automation. And 3PLs are getting more accustomed to it... in addition to just understanding automation better, I think there's an understanding of kind of the journey of scaling up automation and understanding this is a multi year process." [Vecna Robotics]

- Manufacturing companies also tend to be more experienced with managing automation projects

"Most manufacturing companies are used to dealing with the purchase of capital equipment. They usually have internal project and engineering teams that can help specify and deliver projects. Logistics companies are not typically used to buying this sort of equipment and don't necessarily have the teams and skills to manage the complexity of automation projects. We also see that companies have limited knowledge of the contracting side of things, such as having performance-related guarantees in contracts." [Hatmill]

- There can also be regional and company size differences in experience of, and exposure to, automation

"Many North American & European robot companies have existed for 20-30 years. So some of the customers have the experience and knowledge of the automation... but there are a lot of SMBs that don't have this knowledge. Some newer vendors have approached this problem with easier interfaces and more flexibility." [VisionNav]

BROWNFIELD VS GREENFIELD PROJECTS

- There are some differences between projects in brownfield and greenfield environments
- Brownfield projects tend to include a significant level of change management whereas in greenfield projects, robots tend to be part of the workflow from the start

"It is important that customers have built up some knowledge internally. Some of it is seeing the value of ROI at scale as well and I think that's a big part of it. There is a slight difference between brownfield and greenfield projects. When you get into the greenfield design up front and you can build robots into the workflow from the get go, then you don't have to worry about the change management so much." [Vecna Robotics]

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POTENTIAL FOR OVERSIMPLIFICATION WHEN ROBOTS LOOKED SIMILAR TO MANUAL VEHICLES

OVERSIMPLIFICATION OF AUTOMATION

- There is a risk of oversimplifying projects, especially as some vehicles look exactly like manual ones and its attractive to consider it a simple 1:1 replacement
- This may be more prevalent for the forklift form factor

"There's a risk that clients oversimplify things and think, oh, it's just a forklift truck, this could be automated. They usually reach out to their forklift truck provider who can replace their manual trucks with automated versions. However, in reality, it's a completely different system and solution. It may look like the same as having a bum on a seat, but how does the system actually operate? How does the truck communicate? What happens when the mission has been completed? There are also complications associated with removing the human eye, such as, is the pallet ready for automation? Is a profile check now required? Is there shrinkwrap hanging over the pallet? It's easy for companies to simplify AGV projects, particularly trying to mimic their previous manual operations. There's a whole new level of detail required to understand the use case." [Hatmill]

"If you're able to have a well defined process for forklifts, good. But most of the time we think the job of the AGV forklift will be the same as the manual forklift driver. And we are asking the forklift driver to do something different, because he's flexible and he can drive two different forklifts. The guy could jump from one to the other. You could not ask this of a robot." [Kivnon]

OVERSIMPLIFICATION: LIKE FOR LIKE?

Image source: Balyo, Linde Material Handling

WORKFLOW KNOWLEDGE

- However, even when potential customers are aware of their workflows, there are often grey areas in every potential project

"A majority of potential customers know their workflows. I had a lot of projects where we were working over six months just to make all these material flow and movements clear. Because it was never just black and white. It was always nuances of grey." [Sherpa]

- STIQ recommends potential/new buyers of robots walk through and call out current processes, i.e. "I am now removing shrinkwrap from the pallet", etc.
- This may lead to useful insights to the real complexity of current workflows

NOT ALL WORKFLOW PROCESSES ARE EQUAL

- If there is a way to modularize an operation, then mobile robotics may be a suitable option to automate a process/es

"It's always the same. If a customer is able to create modules of their operations that they are doing, then it's better to have a mobile robot doing it. But if you are not able to create these modules of what you are doing, then forget about mobile robots. But yeah, if you're able to modularise it, put a mobile robot on it." [Kivnon]

- Not all processes are amenable to automation

"You have to carefully go through your workflows and find out which are the work tasks we can make manual and which can be automated. And then you just design your system to serve that segment of the automated portion and that's a win-win." [LS LiDAR]

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VENDOR SELECTION, OFTEN AN OVERLY COMPLEX TASK FOR NEW CUSTOMERS

VENDOR SELECTION CAN BE COMPLEX

- The AGV & AMR Robotics market was highly fragmented
- STIQ identified nearly 400 vendors which may represent half of all vendors globally
- One of the reasons the market is fragmented is the ease by which anyone can create an AGV or an AMR
- For new customers, shortlisting suitable vendors is rife with confusing acronyms and terminology
- For customers with AGV & AMR procurement experience, adding new vendors can be a challenge

"When looking to automate your operations, evaluating all aspects is essential. Questions to consider: How are the overall solution's efficiency and the partner's ability to manufacture, deploy, and sustain technology on time and within budget? Is your potential partner well suited in R&D and existing technologies to support your operational needs as they change, grow, and scale? How have prior installations performed against commitments? What does after-sales support entail? It's a congested market, and knowing your partner and the technology deeply is critical as you consider how and where to make your technology investment." [Addverb]

- Interviews suggested vendor selection can be as much as 10-20% of a project
- Understanding both limitations and possibilities can be useful

"Vendor selection is maybe 10-20% of the whole project. What happens before is really understanding the processes, identifying a process that is automatable… and not the most complicated but also promising in terms of ROI." [Waku Robotics]

- Once customers have created a vendor shortlist, will each of the suppliers be able to fulfil RFQs?

"I'm not saying every RFQ out there is wrong, but we've seen a lot of RFQ's that are not going to work in the end based on the demands in the document and it is probably not the best way to do the process. Of course they're going to get quotes from 10 companies. But, how many of those 10 companies are even capable of doing a successful project. Nobody looks at that KPI and they think everybody that bids on the contract at the end will be successful, which is impossible if the project itself is unlikely to be successful." [Anonymous]

THE HEAD OFFICE

- AGV & AMR specification in emerging AGV & AMR markets may be controlled from previous experience in other factories or from the international head office

"A lot of the times Vietnamese factories have a different headquarters somewhere else internationally. If they already have specifications for their automation program, they will copy that here. That's when they have that initiative already. Other times automation managers here will raise a request to the headquarters." [Techvico]

If you are a buyer and want a quick unbiased view on which companies should be included on your shortlist – contact STIQ by email to set up a confidential conversation

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SOME CUSTOMERS APPEARED HESITANT TO ADD AUTOMATION UNLESS THEY COULD HAVE A MANUAL FALLBACK OPTION. KEEPING PEOPLE IN THE LOOP REMAINS IMPORTANT

CUSTOMER APPROACH TO AUTOMATION

- Projects also differ when working with companies with different approaches to automation and how to strategically implement such

"It really depends on the organization. If you have an existing infrastructure, and it's always been running well in manual mode then it's often a tough sell internally. When you have a new organization and they are perhaps more tech centric then it's much easier to adopt automation. Looking at those two organizations is two different answers, but they're quite similar. You need an internal team that's focused and empowered to deploy automation. You'll need to have IT, software, operations, finance, etc. involved in the dialogue pretty much every step of the way. Setting up a project team that can execute is the key to success. It can't be done from one side." [Addverb]

POTENTIAL AUTOMATION WORRIES

- Interviews suggested some customers may be worried about automation not performing to manual standards processes, and asking for manual fallback options

"The way that they work… I don't think they want to switch on fully automatic. There may be some fear about potential problems. So they go very slow. They test a lot. That's also fine tuning and adapting and learning from it and people need to get coached. So it's a slow process. For me, that's an issue because I would like to get them live and use them as a reference for the next implementation." [Samsa Software]

- This could also be part of introducing automation to customers that are new to automation
- Having a fallback option can sometimes offer a level of comfort, but is not often available on larger projects

"For some customers who implement automation… and perhaps it doesn't work the way they wanted. They kind of feel they can fall back to their manual processes. And I think there's still that hesitancy in many companies who want small amounts of automation in the 10s of vehicles, not the 100's." [Guidance Automation]

- When mixing manual and robots, it may be more suitable to include fallback options

"Someone called me and said they had this customer who wants four AGVs, they have scanners and they want a different flow. We don't have that software and the AGV provider doesn't offer that. The customer does a lot of cross docking and they had a lot of problems with this because they used mainly manual ops and they don't have enough workers. But, they also said they don't want to leave the manual out because we don't trust the AGV. So, we created a solution that incorporates manual scanners, etc. and the AGVs. This can switch from more to less manual. We integrate with ERP and WMS to ensure accuracy in the processes and data and locations and so on when workers do things the robots should have done for example." [Samsa Software]

- Most customers appeared to be interested in particular problems, not creating the lights out experience with full automation

"Some companies don't want to change their warehouse into fully automatic. They still want to have something where they are master of their business. I had some customers telling to me, we want to automate, but we want to keep our people in the middle of the process. They could still find people to do things but the customers wanted to have their people doing the intelligent things on what they're doing." [Sherpa]

LIGHTS OUT OPERATIONS?

- This idea of a fully automated warehouse is persistent, but people have to be kept in the loop

"There is this theoretical ideal of a lights out warehouse that automatically does everything. That's probably imaginary in the near future, or at least it's very capital intensive and your ROI may be a decade. And for some people that's fine." [Third Wave Automation]

"Customers often forget that they have created processes which work best when human workers are involved. But when automation comes into play, they need to rethink their processes. Sometimes, this doesn't happen soon enough. Acceptance of the need to change within organizations doesn't develop overnight. A common oversight is the need for trained operations and warehouse staff who, as key users, can handle smaller fixes and workarounds. Intralogistics generally require you to have a team in place who know what the processes are and how they are supposed to run." [Synaos]

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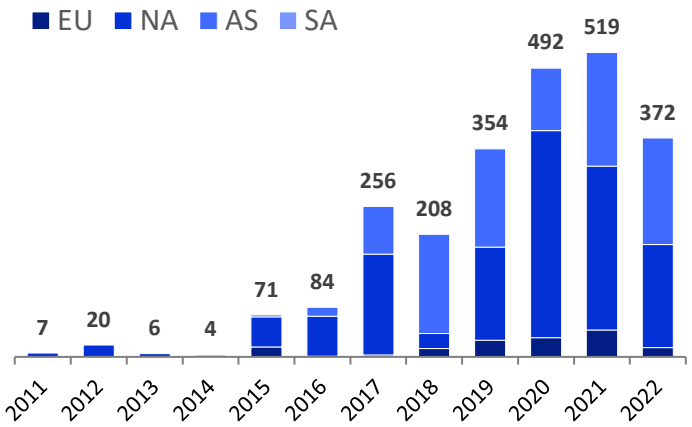
INCREASING FUNDING INFLOWS CONTINUED IN 2021 & 1H22. INFLATION AND POTENTIAL IMPACTS ON DEMAND APPEARED TO REFOCUS INVESTMENT STRATEGIES IN 2H22

ANNUAL AGV & AMR ROBOTICS FUNDING, 2011-2022 ($m)



Note: 2022 funding to September. Differs from previous reports
Source: STIQ Research & Analysis, Crunchbase. Publicly known investments

FUNDING CONTINUED TO INCREASE TO 2021

- Note 2022 funding figures include up to Sep 2022
- Overall investments in AGV & AMR companies continued to increase up to end 2021
- Investments in North American [NA] companies peaked at c.$350m in 2020 and declined to c.$280m in 2021 with a further decline in 2022
- Asian [AS] startup investments declined in 2020, but recovered to c.$190m in 2021 and maintained a similar level in 2022
- Investments in European [EU] startups also increased in 2021 but experienced a decline in 2022

VALUE ON COURSE FOR RECORD, BUT…

- In 1H22 funding inflows appeared to be heading for another record year
- However, Russia's war, inflationary pressures, increasing interest rates and potential for a recession appeared to curtail investment activity from 2Q22
- Interviews and media reports highlighted that VC funds have become very cautious from 2H22

"There's probably a little correction to availability of capital… but there's also the demand and uncertainty… both with prices going up and demand going down due to several factors… and therefore we may also see some of the startups going belly up because they cannot get funding." [Anonymous]

"There's definitely been drying up on the venture capital side. I think investors are getting much more conservative and want to see a path to profitability." [Vecna Robotics]

"Capital is shrinking in the current climate." [Anonymous]

"We attend a few scaleup meetings and I did not realize but other companies were quite in a panic mode because investors are kind of holding up right now. The reason they explained is that investors still have a lot of cash and that's not a problem. But they keep cash for the companies where they are already invested in case they need more." [Anonymous]

"I don't think it's any secret that capital markets in the US at the moment are more conservative than they were a year ago. We're not in the market right now, so we're not having those actual discussions… but the word on the street is certainly clear." [SVT Robotics]

- Investors appeared to focus on scrutinising deals in more detail with increased due diligence

"Investment money has certainly gotten very tight. There's much more due diligence, much more scrutiny. It's definitely cooled off." [Addverb]

NEAR FUTURE CONSTRAINED

- Furthermore, investors appeared very cautious with investments in new companies, choosing to focus on existing portfolio companies
- Some nervousness among companies looking to raise funds in 2023

"We are planning to raise funding next year. We'll see how this is going and what instrument we want to pursue. The big question is… is now the worst we're going to see in the next couple of years. Or is actually going to get even worse?" [Anonymous]

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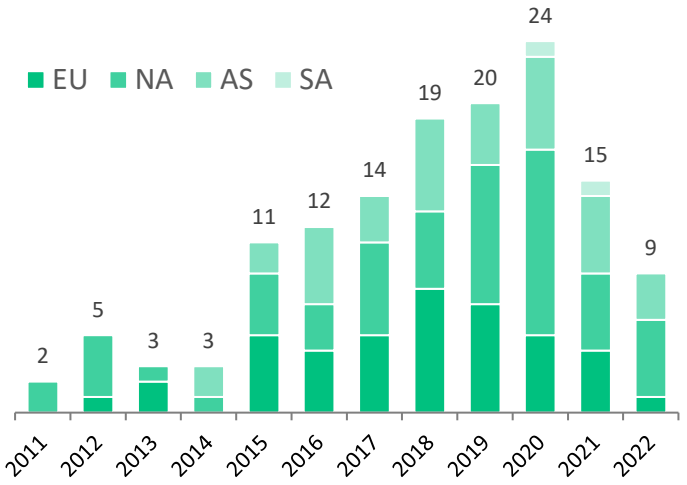
INVESTORS INCREASINGLY CAREFUL WHEN AND HOW TO DEPLOY CAPITAL. STARTUPS MANAGING NEW EXPECTATIONS

ANNUAL AGV & AMR ROBOTICS FUNDING ROUNDS, 2011-2022 S (#s)



Note: 2022 funding rounds to September. Differs to previous reports
Source: STIQ Research & Analysis, Crunchbase. Publicly known rounds

INVESTMENT ROUNDS PEAKED IN 2020

- The number of funding rounds in the AGV & AMR Robotics sector peaked in 2020
- North American funding rounds peaked with the overall market in 2020 whilst European rounds peaked in 2018
- There was no discernible change in the number of investment rounds in Asia

STARTUPS MANAGING EXPECTATIONS

- A few startups had gone back to investors with scaled down growth plans to manage future expectations

"You got the war in Ukraine, Covid not completely over. In January we stripped down our super aggressive growth and revenue goals. We talked to our investors and made them a little bit more realistic. But we're still expecting growth and it's still a good way to go. We believe strongly in the market. It's just there is a weaknesses now. So it's not that there's now a point where you say ok, this kind of solution is not required. It's more that customers have not been ready for what's happening. So, it's just an adjustment." [Anonymous]

- This included taking a bit more time with certain activities instead of pouring money to reap faster results

"The thing I think that affected us more is the investment community and how fast we can scale. And so the big change that we've made may be in our strategy is that instead of scaling ahead of the actual milestones, we're scaling at the milestones. Because the downside is potentially much worse… We are more careful with our cash flow. So basically … the time versus money equation has changed a little bit. We're willing to spend more time in order to maintain our capital." [Anonymous]

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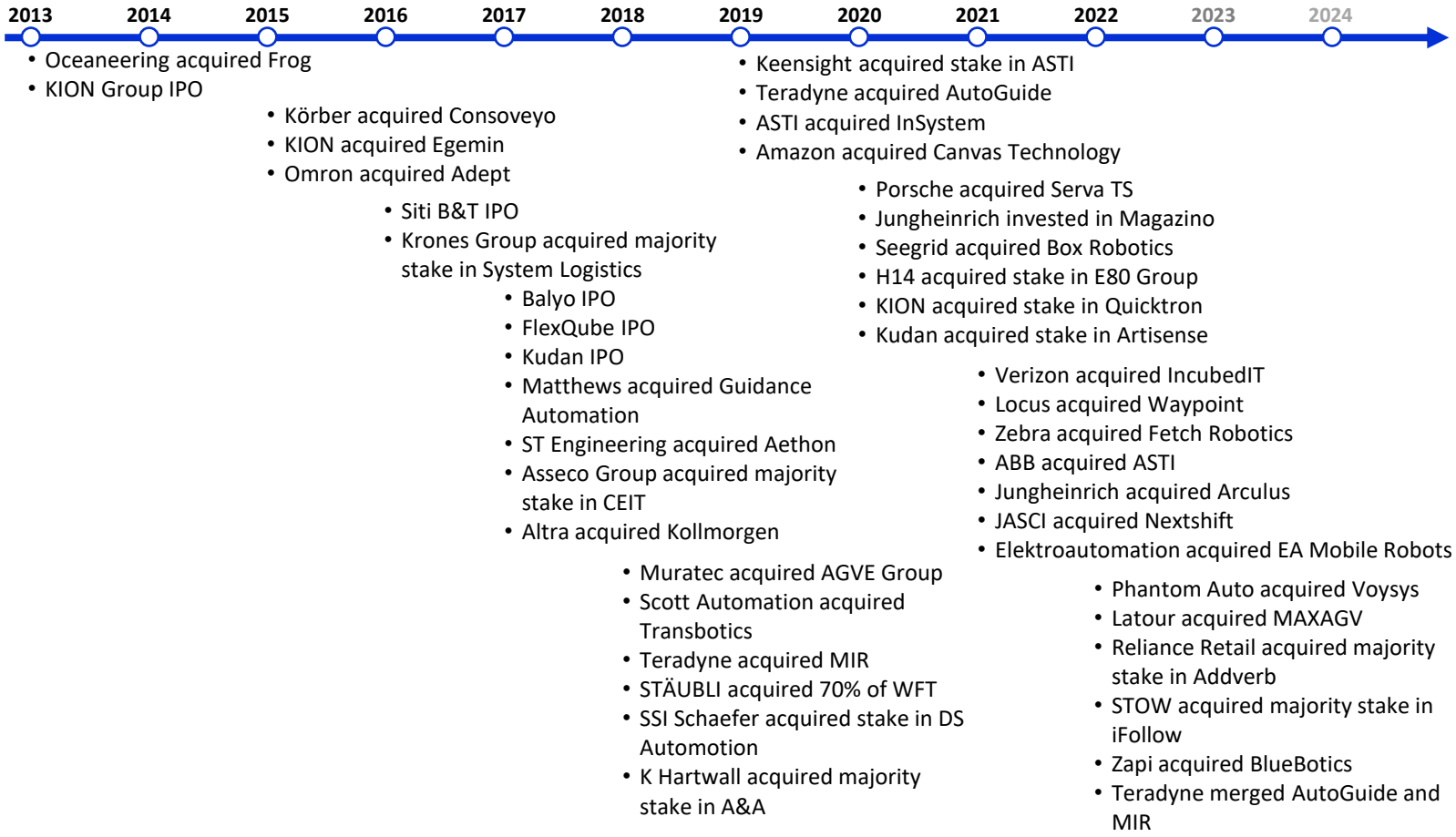
STEADY M&A ACTIVITY IN THE WIDER SECTOR CONTINUED IN 2022. POTENTIAL FOR MORE OPPORTUNISTIC TRANSACTIONS IN 2023 AS COMPANIES MAY RUN OUT OF CASH

SELECTED AGV & AMR ROBOTICS SECTOR M&A, 2013-2022



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 are covered in STIQ's G2P Solutions reports alongside KION's investment in Quicktron, etc. (download STIQs G2P reports here for free).

"NORMAL" M&A ACTIVITY IN 2022

- There has been a relatively high level of M&A activity in the AGV & AMR Robotics sector since the mid-2010's which has continued into 2022
- Corporate buyers have dominated acquisitions in the sector with few Private Equity (PE) buyouts
- A rare exception was Latour's 2022 acquisition of MAXAGV (ATAB and Soft Design)
- Despite the considerable M&A activity, a lack of PE involvement in the sector may be due to limited exit opportunities at acceptable multiples in the sector
- Corporate acquisitions were likely driven by product bolt-on strategies and/or access to technology/ engineering staff
- Few acquisitions appeared to have been driven by access to customers

STIQS VIEW ON M&A IN 2023?

- STIQs view on 2023 was that M&A volume may continue
- Primary reasons:
  - Increased market traction & backlogs
  - Potential for strained cash flow from supply chain disruptions as delivery may be severely delayed alongside lower margins
- Corporate buyers will be in prime position as venture capital has dried up and investors appeared focused supporting existing portfolio companies

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AMAZON – PROTEUS: "WHOLE SYSTEM THINKING" LIMITED BY EXISTING FOCUS ON KIVA SYSTEMS? ACQUISITION OF CLOOSTERMANS?

AMAZON PROTEUS AMR

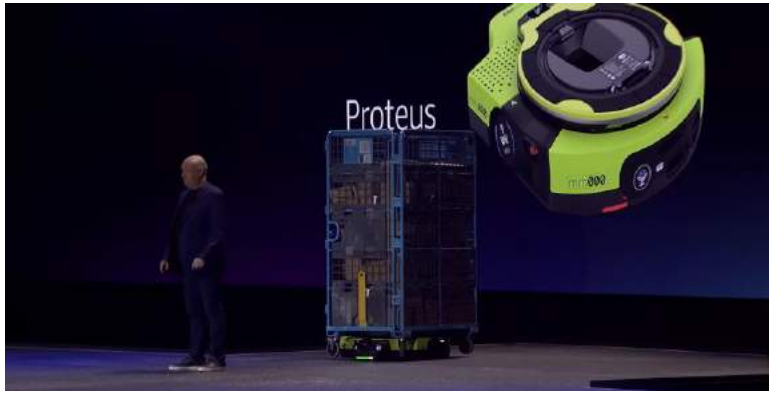


Image source: Screenshot from Amazon Re:Mars, day 2; Tye Brady & Proteus (link)

NEW AT AMAZON: PROTEUS AMR

- Amazon announced the Proteus AMR at their 2022 Re:Mars conference (different from the "Kiva bots")
- In 2019, Amazon acquired Canvas Technology, an AMR vendor; STIQ presumed Proteus may be using some of the technology developed by Canvas
- The robot appeared similar in functionality to other existing mouse vehicles on the market in that it comes with a lifting platform
- Proteus has a relatively unique "face design" which appeared partly created for transporting cages where the cage wheels may obstruct sensors
- STIQs view is that Proteus will not replace any of the Kiva Systems robots deployed at Amazon to date, but will rather focus on other processes

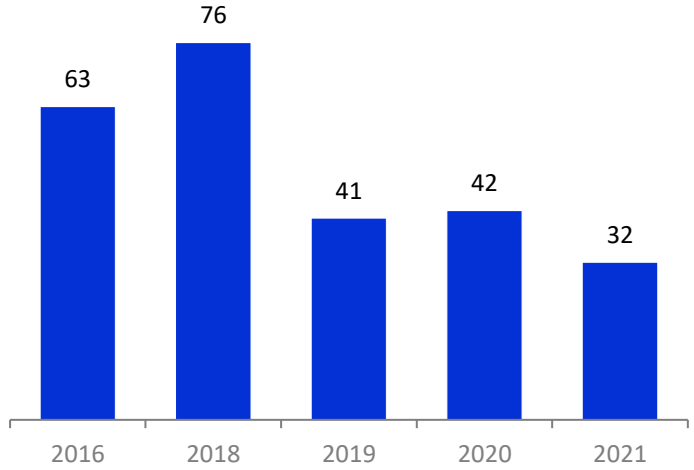
MORE "SOLUTION THINKING" AT AMAZON

- The majority of the 520,000 mobile robots deployed at Amazon (Source: Amazon Re:Mars, 2022) are likely to be of the Kiva Systems/G2P variety (see STIQ G2P Solutions reports here)
- Proteus appeared to be an acknowledgement that Kiva Systems QR navigated robots will form the core of Amazon's storage & retrieval system, i.e. replacing 520k robots is a mammoth task with a huge cost
- STIQs view was that Amazon will be replacing the Kiva Systems "shelf pods" with shelves containing storage totes like the ones used in ASRS shuttle solutions
- A key advantage of moving to storage totes is this allows Amazon to start using picking robots in the put-away and picking processes (see STIQs G2P reports here)
- Proteus is likely to be deployed in non-storage & retrieval processes, i.e. moving of order totes and cages in sortation and consolidation processes

AMAZON + CLOOSTERMANS?

- In Sep 2022, Amazon acquired D Cloostermans-Huwaert, a mechatronics innovation consulting company founded in Belgium in 1884
- The acquisition was "quietly" announced in this AboutAmazon blog (source)
- Amazon worked with Cloostermans in 2019
- STIQs research highlighted that Cloostermans revenue declined since 2016
- A speculative view of the transaction may be that Amazon decided to acqui-hire Cloostermans and save it from a potential default

D CLOOSTERMANS-HUWAERT REVENUE, 2016-2021 (€M)



Source: Company financials

AMAZON, THE SEED INVESTOR

- In 2022, Amazon appeared to have realised its internal innovation is primarily centred on its huge estate of deployed robots and launched an early stage investment fund to identify new exciting innovations

"... and we will always innovate on behalf of our customers. We also realise not everything has to be innovated internally. So, this year we started a new industrial innovation fund where we're investing $1billion to help seed some amazing companies doing some great work here in the early days of robotics, the barnstorming days." [Tye Brady, Amazon, Re:Mars 2022, link]

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VENDOR PROFILES: A-A

ADDVERB

IN | 2016 | US,NL,SG

- Provides end-to-end customized fixed and flexible automation solutions with in-house manufactured hardware and software in India. Addverb's vast offerings include a versatile range of AMRs, ASRS, AGVs, Picking Solutions by Light, Voice and Vision, WMS, WCS, WES, and Fleet Management System.
- Majority stake acquired for $132M by Reliance, a Fortune 500 multinational conglomerate based in India.
- Customers – Reliance, Unilever, PepsiCo, Coca Cola, Amazon, Johnson & Johnson, Panasonic, Diageo, Colgate Palmolive, Janio Asia, Flipkart, ITC, Marico, Dabur, and others.
- Contact: automate@addverb.com

Accerion

NL | 2015 | -

- Provides a mobile robot localization solution

AgileX

CN | 2016 | -

- Provides mouse vehicles (as part of larger mobile robots range)

Company Profiles: How to read?

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

Squares are links to:

- W = company website
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- Cb = Crunchbase profile
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Agilox

AT | 2017 | -

- Provides forked vehicles

Aitech

SG | 2013 | -

- Provides mouse vehicles

Aiten Popifyindustrial

CN | 2017 | -

- Provides mouse and forked vehicles

Alias Robotics

ES | 2018 | -

- Provides robot cyber security solution

Alstef Group

FR | 1961 | Global

- System integrator with forked and mouse vehicles
- Merged with BA Systemes in 2018

Anantak Robotics

US | 2014 | -

- Provides navigation software solution

Anronaut

CH | 2002 | -

- Provides forked vehicles

Arculus

DE | 2016 | Global (parent co)

- Provides mouse vehicles
- Acquired by Jungheinrich in 2021

VENDOR PROFILES: A-C

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ASTI Mobile Robots

ES | 1982 | Global (parent co)

- Provides tugger, mouse and forked vehicles
- Acquired by ABB in 2021 for $190m

Autoguide Mobile Robots

US | 2018 | -

- Provides tugger, forked vehicles
- Acquired by Teradyne in 2019 for $165m
- Merged with MIR in 2022

Automni

BR | 2014 | -

- Provides forked vehicles

Avidbots Corp.

CA | 2014 | US

- Provides floor cleaning robots

Balyo

FR | 2005 | US

- Provides forked vehicles
- IPO in 2017

BAR Automation

DE | 1972 | -

- Provides mouse vehicles

BlueBotics

CH | 2001 | Global (Parent)

- Provides a navigation solution
- Acquired by Zapi Group in 2022

Bosch Rexroth

DE | 1795 | Global

- Provides a navigation solution
- Subsidiary of the Bosch Group

Botsync

SG | 2017 | -

- Provides mouse vehicles

Bowe Group

DE | 1945 | Global

- System integrator with forked vehicle

Brisa

BR | 2018 | -

- Provides forked vehicles

Casun

CN | 2007 | -

- Provides mouse, tugger, forked vehicles

CEIT

SK | 1998 | -

- Provides mouse and tugger vehicles
- Acquired by Asseco Group in 2017

Cleanfix

CH | 1976 | -

- Provides a floor cleaning robot

Comau

IT | 1973 | Global

- Provides mouse vehicle, industrial robots

VENDOR PROFILES: C-G

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Continental

DE | 1871 | Global

- Provides mouse vehicle
- The business is a segment within the Continental Automotive business unit

Daifuku

JP | 1937 | Global

- System integrator with mouse, tugger and forked vehicles
- IPO in 2017

Dematic

US | 1819 | Global

- System integrator with mouse, tugger and forked vehicles
- Acquired by KION Group in 2016 for $2.1bn

DS Automotion

AT | 1984 | -

- Provides mouse, tugger and forked vehicles
- Acquired by SSI Schaefer in 2018 (majority stake)

DTA

ES | 1974 | -

- Provides very high payload mouse vehicles

E80 Group

IT | 1980 | Global

- System integrator with forked vehicles

EA Mobile Robotics

SE | 1986 | -

- Provides mouse vehicles
- Acquired by Elektroautomatik in 2021

EK Robotics

DE | 1980 | UK,IT,CZ

- Provides mouse, tugger and forked vehicles

FARobot

TW | 2020 | -

- Provides mouse vehicles, fleet management solution
- Joint Venture between ADLINK and FOXCONN

Fetch Robotics

US | 2014 | Global (parent co)

- Provides mouse vehicles
- Acquired by Zebra in 2021 for $290m (EV $310m)

FlexQube

SE | 2010 | US

- Provides mouse vehicles
- IPO in 2017

ForwardX

CN | 2016 | US

- Provides mouse and forked vehicles

Fusion Processing

UK | 2012 | -

- Provides an autonomous vehicle stack

Geek+

CN| 2015 | US,JP,DE,UK,SG,

- Provides mouse and forked vehicles

Gideon

HR | 2017 | -

- Provides mouse and forked vehicles

VENDOR PROFILES: G-L

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GIM Robotics

FI | 2014 | -

- Provides navigation software solution

Grenzebach

DE | 1960 | Global

- Provides mouse vehicles

Guidance Automation

UK | 1990 | Global (parent co)

- System integrator
- Acquired by Matthews International in 2017

idealworks

DE | 2020 | Global (parent co)

- Provides mouse vehicles
- Part of BMW group

iFollow

FR | 2017 | Global (parent co)

- Provides mouse vehicles
- Acquired by STOW in 2022 (majority stake)

IncubedIT

AT | 2011 | -

- Provides navigation software solution
- Acquired by Verizon in 2021

IPLUSMOBOT

CN | 2016 | -

- Provides mouse and forked vehicles

JBT Corp

US | 1894 | Global

- Provides mouse, tugger and forked vehicles

Karter

NL | 2021 | -

- Provides forked vehicles
- Part of Weighpack

Kivnon

ES | 2007 | -

- Provides mouse, tugger and forked vehicles

Körber Business Area Supply Chain

DE | 1946 | Global

- System integrator

Kollmorgen

SE | 1972 | Global

- Provides navigation software solution

Kudan

JP | 2011 | UK,DE,US

- Provides SLAM localization solution
- IPO in 2018

LS LiDAR

CN | 2015 | US

- Provides navigation software solution

Lemurian Labs

CA | 2018 | -

- Provides SOC (neural SLAM)

VENDOR PROFILES: L-O

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Linde Material Handling

DE | 1904 | Global

- Provides tugger and forked vehicles
- Acquired by KION Group in 2007

Lowpad

NL | 2017 | -

- Provides mouse and forked vehicles
- Part of Eurogroep

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MAXAGV

SE | 2004 | -

- Provides mouse, tugger and forked vehicles
- Acquired by Latour in 2022

Mitsubishi Logisnext

FI | 1942 | Global

- Provides forked vehicles
- [Rocla] Acquired by Mitsubishi in 2008

MIR (Mobile Industrial Robots)

DK | 2013 | Global

- Provides mouse vehicles
- Acquired by Teradyne
- Merged with Autoguide Mobile Robots in 2022

Mov.ai

PT | 2016 | IL

- Provides navigation software solution

Muratec

JP | 1935 | Global

- System integrator with mouse, tugger and forked vehicles

NAiSE

DE | 2017 | -

- Provides agnostic fleet management solution

Navflex

DE | 2020 | US

- Provides forked vehicles

Navitec Systems

FI | 1998 | US

- Provides navigation software solution

Nipper AGV

NL | 2013 | -

- Provides forked vehicles
- Part of F3 Design

Nvidia

US | 1993 | Global

- Provides compute & software solution

OCME

IT | 1954 | US,MX,SA,CN,TH

- Provides mouse and forked vehicles

Omron

JP | 1933 | Global

- Provides mouse vehicles, cobots, industrial robots
- Acquired Adept in 2015

VENDOR PROFILES: O-S

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Oppent

IT | 1960 | ES,TR,DE,FR,AE

- Provides mouse and tugger vehicles

Outrider

US | 2017 | -

- Provides yard transportation vehicle

Phantom Auto

US | 2017 | -

- Provides remote controlled software solution for forked vehicles

Proxima Robotics

IT | 2018 | -

- Provides navigation software solution

Rgo Robotics

US | 2018 | -

- Stealth mode (appears to provide localisation and/or navigation software solution)

Robotize

DK | 2016 | -

- Provides mouse vehicles

Romb Technologies

HR | 2018 | -

- Provides navigation software solution

Safelog

DE | 1996 | US

- Provides mouse and tugger vehicles

Samsa Software

NL | 2016 | -

- Provides AGV & AMR middleware software solution

Scott Automation

AU | 1982 | Global

- Provides mouse, tugger and forked vehicles
- [Transbotics] Acquired by Scott Automation in 2018 for c.$5m

Seegrid

US | 2003 | -

- Provides tugger and forked vehicles

SEER

CN | 2015 | -

- Provides vehicle chassis (and controllers)

Sevensense Robotics

CH | 2018 | -

- Provides navigation software solution

Sherpa Mobile Robots

FR | 2020 | -

- Provides mouse vehicles
- Part of Norcan

SICK

DE | 1946 | Global

- Provides SLAM localization software (and sensors)

VENDOR PROFILES S-W

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Standard Robots
CN | 2015 | -
- Provides mouse vehicles

SVT Robotics
US | 2018 | -
- Provides AGV & AMR middleware software solution

Synaos
DE | 2018 | -
- Provides agnostic fleet management solution

Synersight
ES | 2017 | -
- Provides mouse, tugger and forked vehicles

System Logistics
IT | 1986 | Global (Parent)
- System integrator with mouse and forked vehicles
- Acquired by Krones in 2016 (majority stake)

Techvico
VN | 2093 | TH
- Provides navigation software solution

Third Wave Automation
US | 2018 | -
- Provides forked vehicles

Toyota Advanced Logistics
JP | 2017 | Global
- Provides mouse, tugger and forklift vehicles
- Part of Toyota Group

Vecna Robotics
US | 1998 | -
- Provides tugger and forked vehicles
- Spun out from Vecna Technologies in 2018

Versabox
PL | 2013 | -
- Provides mouse vehicles

VisionNav Robotics
CN | 2016 | -
- Provides forklift vehicles

Waku Robotics
DE | 2019 | -
- Provides agnostic fleet management solution

Wheel.me
NO | 2013 | -
- Provides single wheel robots

ADVERTISE WITH STIQ
UK | 2018 | -
- Download STIQs media pack for advertising opportunities reaching vendors, buyers, component suppliers, system integrators, investors and many others here

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CREDITS & INTERVIEWEES, TRADE SHOWS, GLOSSARY

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INTERVIEWS - AGV & AMR HW/SW VENDORS:

- Accerion (NL) CEO
- **Addverb (IN) CRO, Americas**
- **Addverb (IN) CEO, Americas**
- **Addverb (IN) CEO, EMEA**
- Agilox (AT) CMO
- Aiten/ Popifyindustrial (CN) General Manager
- Alstef Group (FR) Sales Director
- BlueBotics (CH) CEO
- Bosch Rexroth (DE) Projects Director
- Continental (DE) Head of Product Line Intralogistics
- DTA (ES) Head of Sales
- FARobot (TW) Product Manager
- ForwardX (CN) VP of US
- Fusion Processing (UK) CEO
- Geek+ (CN) GM M&F Overseas
- Gideon (HR) Executive Operations Manager
- Guidance Automation (UK) Managing Director
- iFollow (FR) CEO
- IPLUSMOBOT (CN) Overseas Business Director
- Karter (NL) Commercial Manager
- Kivnon (ES) Managing Director
- Körber Business Area Supply Chain (DE) VP AMR
- Kollmorgen (SE) Product Management Director
- Kudan (UK) COO
- Lemurian Labs (CA) CEO & Co-founder
- LS LiDAR (CN) BDM, North America
- MIR (DK) VP Marketing & Strategy
- Muratec (US) National Sales Manager
- NAiSE (DE) CEO & Co-founder
- Nvidia (US) Product Management Director
- Omron (ES) European Product Manager
- Proxima Robotics (IT) CEO
- Romb Technologies (HR) Director
- Safelog (DE) CEO
- Samsa Software (NL) Founder
- SEER (CN) Head of Overseas Business
- Sevensense (CH) CBDO
- Sherpa (FR) CSO
- SICK (DE) Industry Management
- SVT Robotics (US) Sr Director of Marketing
- Synaos (DE) CPO & Co-founder
- System Logistics (IT) Head of Market Operations
- Techvico (VN) CEO
- Third Wave Automation (US) CEO & Co-founder
- Vecna Robotics (US) Director Product Marketing & Strategy
- VisionNav (CN) VP Global Sales
- Waku Robotics (DE) CEO & Co-founder
- Wheel.me (NO) Founder

INTERVIEWS - COMPONENT SUPPLIERS:

- Conductix-Wampfler (DE) [Energy Mgmt] [Web]
- FES AES (DE) [Hydrogen Power] [Web]
- Flowcate (DE) [Location System] [Web]
- Hatmill (UK) [MH Consulting] [Web]
- Ketterer (DE) [Drive systems] [Web]
- Maxon (CH) [Drive Systems] [Web]
- Robex (US) [Reseller/System Integrator] [Web]
- Toposens (DE) [Sensor] [Web]
- Wiferion (DE) [Energy Mgmt] [Web]

INTERVIEWS - USERS & BUYERS:

Multiple companies & individuals that requested anonymity including global 3PLs and manufacturers

We're extending a big thank you to these contributors!

- [Anonymous AGV & AMR User] (Factory-based)
- [Anonymous 3PL] (Warehouse/3PL)

EVENTS (STIQ RECOMMENDS):

- Automatica (DE) [Web]
- CeMAT (DE) [Web]
- IMHX (UK) * [Web]
- Logimat (DE) * [Web]
- Modex (US) * [Web]

GLOSSARY

3PL	Third Party Logistics
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)
Fiducial	Marker used to localise a robot
FM	Fleet Manager
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 Localisation System
Sensor Fusion	Combination of multiple sensors
SLAM	Simultaneous Localisation and Mapping
SMB/SME	Small & Medium Businesses (US/UK)
TCO	Total Cost of Ownership
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


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