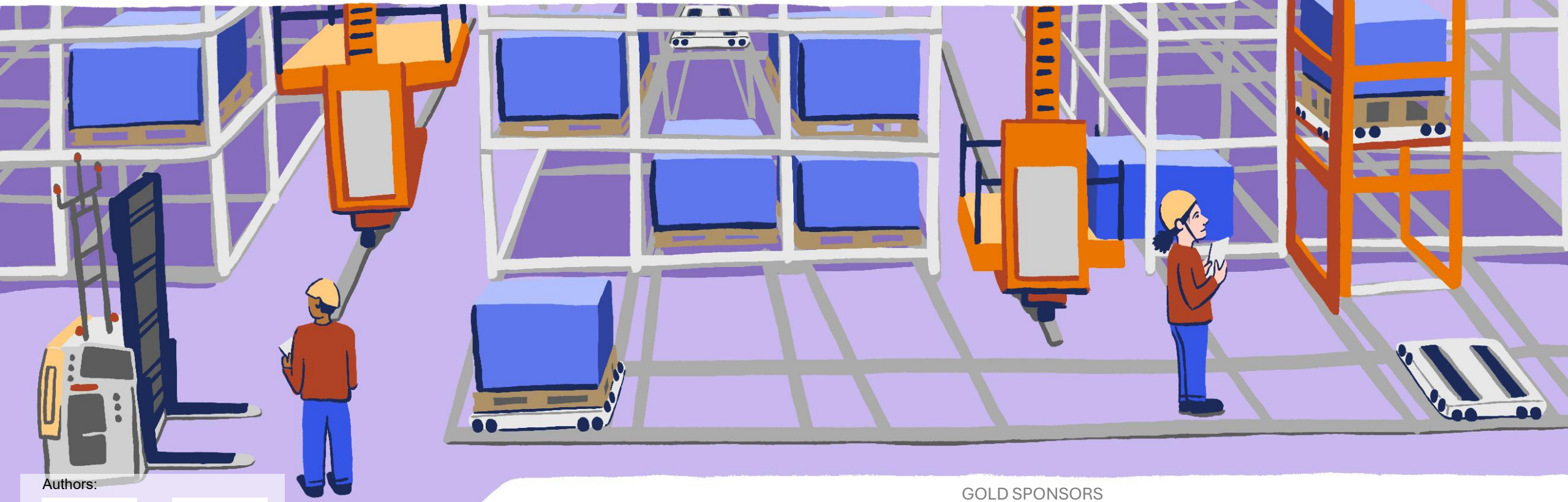
PALLET AUTOMATION 2026

PALLET STORAGE & RETRIEVAL | PALLET SHUTTLES | STACKER CRANES | PALLET ASRS

Pallet ASRS Automation 2026
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EXEC SUMMARY: INCUMBENT PALLET ASRS SYSTEMS EXPERIENCE STABLE GROWTH WHILE 2D SHUTTLES EXPANDING INTO WHITE SPACE AND TAKING MARKET SHARE

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THE GLOBAL PALLET ASRS MARKET

- This report focuses on the global Pallet ASRS market (cranes, mother-child shuttles, 1D shuttles) and the popularity of the 2D shuttle (note: in this report we refer to 4-way shuttle as 2D shuttle)
- Stacker cranes emerged in the 1960s, followed by 1D shuttles in the 1990s, Mother-Child shuttles in the 2000s and most recently the 2D shuttle in the 2010s
- Early developments in the 2D pallet shuttle market mirror events in the G2P Solutions sector where growing demands on flexibility and scalability converted many customers and opened up new white space opportunity
- STIQ expects further innovation of 2D shuttles

GROWING POPULARITY OF 2D SHUTTLES

- While the overall pallet ASRS market experiences healthy stable growth, the 2D shuttle segment is growing very fast and is expected to dominate the market in the near future
- The 2D shuttle has opened up new white space in the global pallet ASRS market and overlaps with legacy solutions and is grabbing some degree of market share from incumbent systems
- Primary advantages of the 2D shuttle include density, flexibility and scalability allowing customers to start with fewer robots and scale up as demand grows
- Primary inhibitors for the 2D shuttle include the relatively high proportion of steel/racking, often as high as 50-70% of projects, and pallet quality issues which can require customers to change their pallet inventory to pallets more suitable for automation
- Despite the high % of steel, many customers now specifically request 2D shuttles and there are signs the crane segment may suffer in the medium-term
- ROI for 2D shuttles improves sharply in temperature controlled environments or when they are part of a larger integrated warehouse solution

LIKELY PALLET ASRS MARKET EVOLUTION

- In the medium to longer-term 2D shuttles will likely gain a significant and dominant market position in the global pallet ASRS sector
- While 2D shuttle technology has been around for about a decade, it remains relatively nascent with plenty of ongoing end-customer and system integrator experimentation
- Racking suppliers are also offering more standardized profiles to encourage improved pricing and push further adoption
- Stacker cranes and Mother-Child shuttles will likely remain in the market, especially if pricing for racking/ steel is improved for 2D shuttles
- The 1D shuttle is mainly used as a first entry into hybrid manual-automated environments with focus on density and is relatively insulated from 2D shuttle competition

FUTURE, MIXED PAYLOAD EXPANSION

- There are already signs that 2D shuttles are entering multiple payload scenarios, such as fulfilment for pallets and cases
- While pallet stability and safety are concerns, it is likely this will be overcome, especially for opened pallets that hypothetically can move between storage and pick faces

FOR BUYERS OF PALLET ASRS systems:
STIQ offers a free 30min debrief/Q&A session for this report as part of the sponsorship. Contact us to arrange a confidential "ask us anything" session

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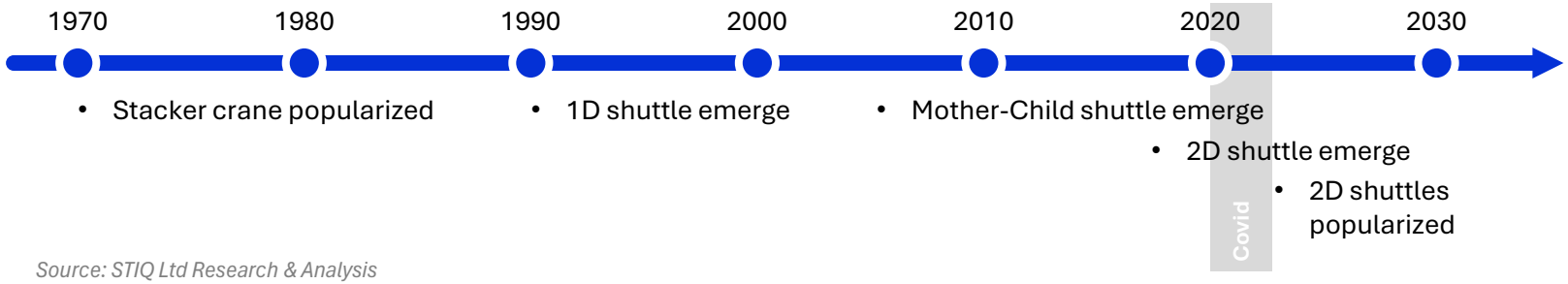
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THE PALLET ASRS SECTOR HAS DEVELOPED RELATIVELY SLOWLY SINCE AROUND THE 1970s

HISTORICAL DEVELOPMENT OF PALLET ASRS SYSTEMS, 1970-2030



Source: STIQ Ltd Research & Analysis

HISTORICAL DEVELOPMENT OF PALLET ASRS

- Pallet ASRS automation development began in the 1950s with the development of the pallet stacker crane (by Demag) which was popularized in the 1960-70s
- This was followed by the development of the 1D shuttle in the 1990s, the Mother-Child shuttle in the mid-2000s and most recently the 2D pallet shuttle in the 2010s
- Overall adoption of MHE automation has followed a similar trajectory

"I've worked here for over 35 years. In the early days, obviously there was not a lot of automation... because there were not a lot of ASRS systems and nowadays it's all over the place. And the threshold for investing into automation or semi-automation has lowered quite a bit, especially with AMRs and now also with 2D shuttles." [NEDCON]

PARALLEL DEVELOPMENTS IN G2P SOLUTIONS?

- Pallet ASRS automation development has been relatively slow, especially when compared to other MHE sectors such as G2P Solutions (download STIQ reports on G2P here)
- The 'golden age' of G2P Solution innovation was in the mid 2010s, early 2020s with sharp market traction catalysed by Covid which led to a huge boost in ecommerce and associated fulfilment activity
- While the high degree of product innovation in the G2P sector has not yet occurred in the pallet sector, recent developments in the 2D Pallet Shuttle segment may hint at more innovation to come

MOTHER-CHILD PREPARING FOR 2D SHUTTLE

- Both the 1D and the Mother-Child shuttle have paved the way for the 2D shuttle to emerge in the 2010s and be popularized around Covid

"The Mother-Child shuttle kind of paved the way, but not bringing the real advantages of a 2D shuttle. A Mother-Child helps for multi-deep storage. You get the density benefit, but you don't get the flexibility benefit. You need one shuttle in every aisle and one on every level. There are some exceptions where they roam, which is horrific for infrastructure. But you're fixing it for the next 20 years and you cannot change it. It only makes sense if you have very high throughputs, because Mother-Child's are pretty fast. Sometimes in beverage it makes sense, where your bottlers know exactly the cadences that their lines spit out. But you don't have any flexibility. And the market is requesting flexibility. You don't know the throughput, you don't know the batch sizes. You can have deep channels, narrow channels, and shuttles that are not captive." [MOVU Robotics]

COVID BOOST FOR AUTOMATION IN GENERAL

- The MHE sector received a huge boost during Covid which sharply increased automation technology adoption among end customers and also spurred new entrants

"We built our foundation on Class 2 lift trucks, that introduced a surge in demand for racking, and eventually automation... especially during pandemic when we saw a lot of investments in warehouses and automation. All these customers that have been buying forklifts from us are now suddenly asking the question 'hey, what can you do to optimize my warehouse? Because I'm seeing everyone else invest'. It only became natural post-pandemic and we spun up a system integration unit." [Equipment Depot]

NEW 2D SHUTTLE TECHNOLOGY EXPERIENCE MIRRORS OTHER NEW TECHNOLOGY INTRODUCTION, SUCH AS THE EMERGENCE OF THE STACKER CRANE

SOFTWARE DEFINED PALLET AUTOMATION

- In general, the sector is moving away from single purpose and relatively simple technology to new systems with multi-robot fleets and higher complexity, scalability and flexibility

"The industry is moving from a rigid, single-purpose automation to adaptive, intelligent and software-defined ecosystem." [Automha]

NEW TECHNOLOGY, NEW LEARNINGS

- New MHE technologies typically require specialist attention and support from vendors to draw the full benefit of such systems; The stacker crane experience is now mirrored in the recent rise of 2D shuttle technology

"Fifty years ago, when a stacker crane was installed, it was often supported by a resident engineer because operating and maintaining the system required highly specialized expertise. Over time, stacker cranes have become a well-established technology and today many intralogistics professionals are familiar with their management and operation. By comparison, 2D shuttle systems are a more recent development. While they may appear straightforward at first glance, they introduce a different level of complexity and the industry is still building the experience and know-how needed to manage them with the same maturity." [Eurofork]

- The stacker crane is widely adopted and relatively simple technology with a single pallet operation per crane whereas the 2D shuttle offers a new complexity and one pick per shuttle deployed

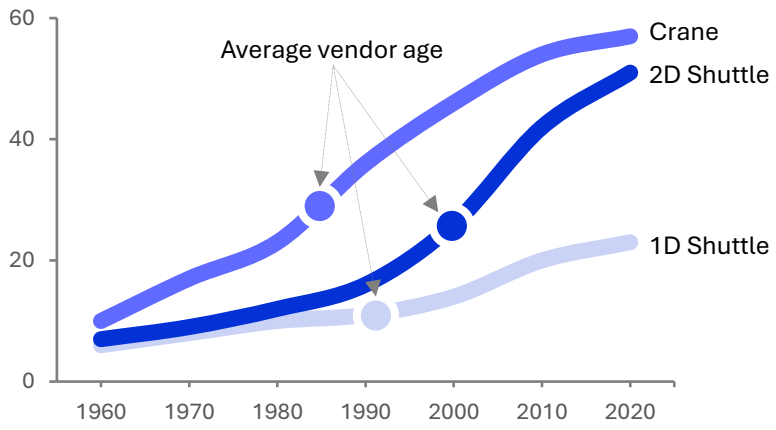
"Stacker cranes have been around since the early 1960s. There's been attempts at deploying triple deep ASRS and then more than triple deep with a satellite vehicle on a stacker crane. But, I think it's really that the software didn't exist 10-15 years ago to do it earlier. Because the route solving piece is more complex than a stacker crane storage algorithm. And then just that communications requirement. We have fleets of multiple vehicles and each time they complete a part of their travel path, it's communicating back where it is, getting the next command." [Aistorage]

RETROFITS FOR EARLY TECH ON THE RISE

- Interviews for STIQ Ltd reports suggest a recent rise in the number of retrofits for early technologies such as stacker cranes as some of the components are becoming obsolete

"The only reason crane customers do a retrofit is because the electronic equipment is getting obsolete. Usually after 15 years or something like that." [Highbay AB]

PALLET ASRS DEMOGRAPHICS, 1960s-2020s (#)



Source: STIQ Ltd Research & Analysis. Year company founded, may be different to when company added product

DEMOGRAPHICS – RISE OF THE 2D SHUTTLE

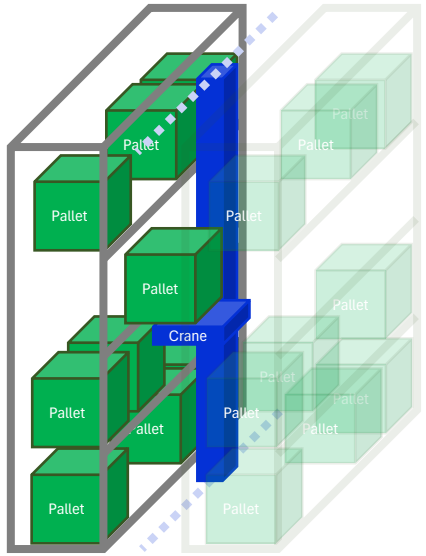
- While the stacker crane was invented in the 1950s, it was not until the 1980-90s that it gained significant market traction followed by growth in vendors
- The 1D shuttle emerged in the 1990s and gained traction in the 2000s
- The 2D shuttle first entered the market around mid 2010s but hardware developments, such as improved battery technology, led to improved form factor and functionality and the system gained significant market traction in the 2020s with a huge spike in 2D shuttle vendors

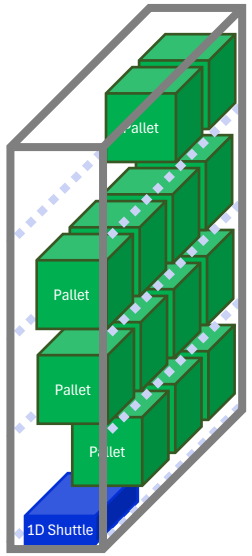
THERE ARE FOUR PRIMARY PALLET ASRS TECHNOLOGIES ON THE MARKET. HYBRIDS, SUCH AS STACKER CRANES WITH SATELLITE SHUTTLES ARE ALSO OFFERED

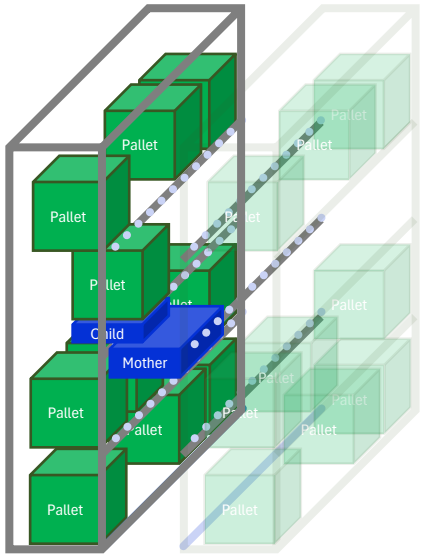
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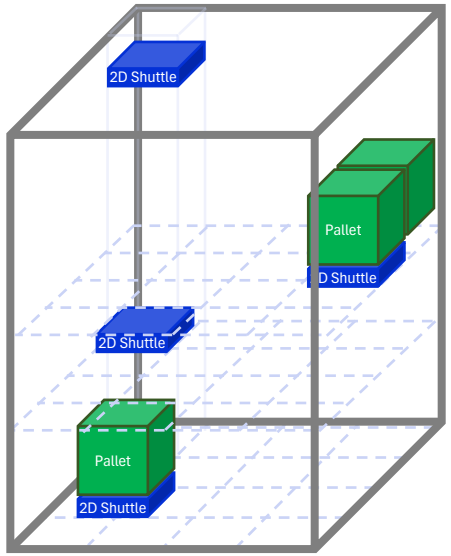
THE PRIMARY PALLET ASRS SYSTEMS (SIMPLIFIED)

Key:
- *Robot*
- *Storage/ Fixture*
- *Movement (axis)*
- *Guide, Rail (only for explanation)*









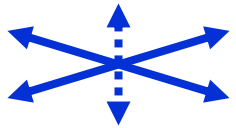
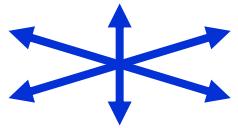
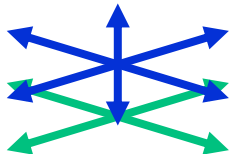
Type	Stacker Crane	1D Shuttle	Mother-Child Shuttle	2D Shuttle
Alternative Name	n/a	2-Way or Satellite Shuttle	Mother-Daughter	4-way Shuttle, Roaming Shuttle
Robot Moves on	Rails (ground + top)	No	Rails in storage	Rails
Typical depth	1-2 pallets	Unlimited	1-2 pallets	Unlimited
Max Height	>50m	<10m *	<40m *	<30m *
Power transmission	Contact	Battery	Contact	Battery
Movement	Crane X-Z, Load carrier Y	X (forward/backward), Moves between aisles using manual forklift	Shuttle X, Child Y	Shuttle, X-Y, Lift Y (Shuttle move)
Hybrid options	Satellite load carrier	n/a	n/a	Move on ground as AGV *

Source: STIQ Ltd Research & Analysis
** Market is changing quickly and the suitable height is often determined by comparable ROI rather than product limitations*

THERE ARE FOUR PRIMARY PALLET SHUTTLE TYPES ON THE MARKET CURRENTLY: MOTHER-CHILD, 1D, 2D AND 3D. NEW DEVELOPMENTS LIKELY IN THE SHORT- TO MEDIUM-TERM

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PRIMARY PALLET SHUTTLE FORM FACTORS (SIMPLIFIED)

Pallet Shuttle Type	Mother-Child Shuttle	1D Shuttle (2-Way, Satellite Shuttle)	2D Shuttle (4-way Shuttle)	3D Shuttle	3DM Shuttle (3D + Mobile robot)
Image					??
Dimensions (Movement)					
Movement Location	Exclusively in fixture				Fixture + Floor

Key: ↔ *Free movement* ↔ *Movement using lift* ↔ *Floor movement*

Source: STIQ Ltd Research & Analysis
Image source: Swisslog, BT, ZS Robotics, Mytra

CURRENTLY, FOUR PRIMARY SHUTTLE TYPES

- The pallet shuttle space is developing fast and currently, there are 4 primary shuttle types on the market: Mother-Child, 1D, 2D and 3D
- True 3D shuttles remain uncommon, however, the market is likely to develop new types of shuttles and the most likely development route is 3DM, where a shuttle comes with the ability to move on the ground (not only in a fixture)

1D SHUTTLE SPECIFICS

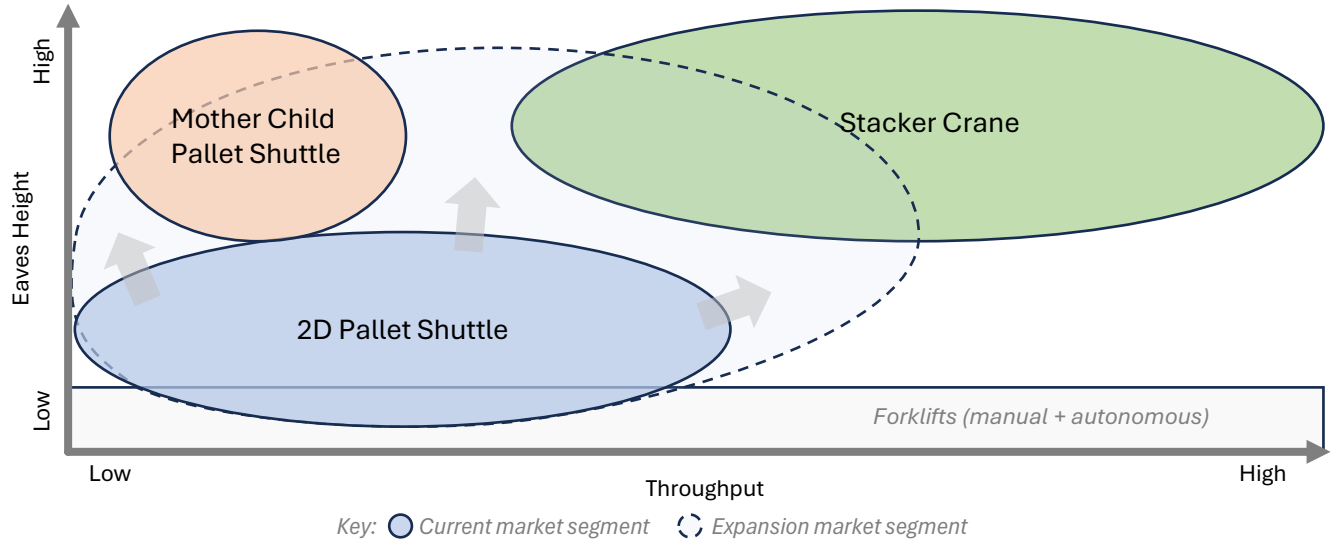
- 1D shuttles are treated separately as this is a hybrid system, primarily used where the market driver is increased storage density
- This is a largely manual operation and the 1D shuttle is activated manually via remote control and only moves between channels (aisles/floors) by being transported by a manual forklift – unless there is already a 1D shuttle in every location

2D SHUTTLE, SIGNIFICANT MARKET TRACTION

- 2D shuttles have experienced significant traction in recent years and have emerged into a relative white space where most other options are relatively inflexible and difficult to scale

THE 2D PALLET SHUTTLE HAS ENTERED A RELATIVE WHITE SPACE IN THE PALLET ASRS SPACE AND IS INCREASINGLY COMPETING WITH INCUMBENT LEGACY ASRS SYSTEMS

PALLET ASRS TYPES BY PRIMARY TARGET MARKET SEGMENT, THROUGHPUT VS EAVES HEIGHT (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

CAVEAT ON PALLET ASRS MARKET OVERVIEW

- Readers should note pallet ASRS systems are measured across multiple dimensions and variables, and the above illustration is a highly simplified single view of market movements
- For more detailed information on pallet ASRS systems, refer to a supply chain consultancy, system integrator or vendor

MANUAL + AUTONOMOUS FORKLIFT OPTIONS

- Interviews for this report have suggested alternatives to pallet ASRS includes fully manual and AGV forklifts (download STIQs AGV & AMR Robotics reports for more information)
- Forklift options (manual or automated) did not feature significantly in STIQs interviews for this report and have been left out from the primary analysis
- Note there were multiple references to the potential of using AGVs to feed in/out to/from 2D shuttles

THE 2D SHUTTLE OVERLAPPING WITH LEGACY

- While the 2D shuttle has emerged into a largely white space in the pallet ASRS sector, it is increasingly overlapping with incumbent legacy technologies such as Mother-Child shuttles and cranes

"The 2D shuttle sits across parts of our pallet ASRS portfolio, creating some overlap in potential applications." [Swisslog]

"There's a little bit of an overlap between cranes and shuttles. Some of it is also end customer preference. Crane system's been around forever and some customers just go with legacy technologies. You can fit the same criteria into a crane or a 2D shuttle. But there are cases where a crane excels or makes more sense. Vice versa, there are cases where a shuttle makes way more sense than a crane. It depends on the ROI and what the end user values too." [Equipment Depot]

- Similarly, interviews also suggest the 2D shuttle is increasingly overlapping with even more advanced crane applications

"We're working on a 42 meter high installation right now." [Logiqs]

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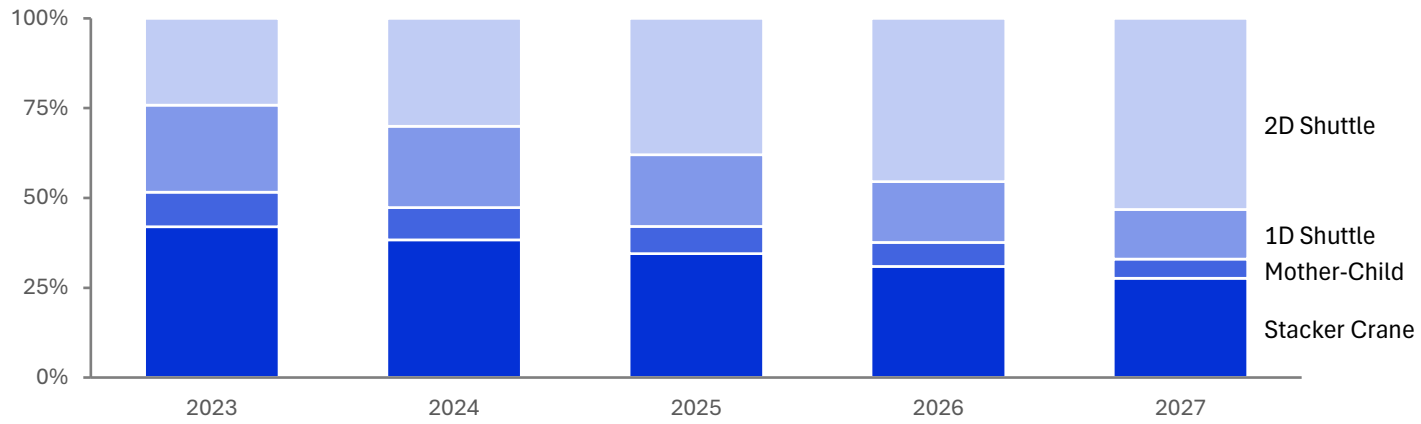
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DESPITE SOME CONCERNS AND LESS VISIBILITY FOR 2027, STIQ FORECAST SIGNIFICANT MARKET GROWTH

THE GLOBAL PALLET ASRS MARKET, SHARE BY TECHNOLOGY, 2023-2027 (% EST)



Source: STIQ Ltd Research & Analysis. Total project size, including racking
Note: For actual market size data, contact STIQ Ltd (or see front page for contacts)

TARIFFS IMPACTED DEMAND IN 2025

- The US administration announced significant tariffs in the start of 2Q25 which negatively impacted automation investments

"Tariffs in the US and the war in Ukraine in 2025… nobody would sign a PO. But when the tariffs stabilised and everybody knew that it was 15% on material and 50% on the steel… at the end of the year, they were confident that they knew what they were buying. The problem in 2Q25 was they did not know if the sign today was the tariff going to increase by this or what their cash flow was actually going to look like." [Anonymous]

2025 WAS RELATIVELY GOOD

- While tariffs impact 2Q-3Q25, interview suggest business picked up as some degree of stability returned and 4Q25 ended up very good

"1Q-2Q25 was very slow in the market. 4Q25 and 1Q26 were busy… 2026 has been very good." [Moffett]

"For order intake, I would give 2025 the highest rating. In that year, we saw many customers move forward with decisions that had been postponed from the previous year." [Eurofork]

"2025 was very good because we achieved some very important references. We are selling systems that will be realized in 1-1.5 years… or more. The turnover in 2026 will be high." [Automha]

"From 2024 to 2025 we doubled our revenue. It can always be better, but we were happy with it." [Logiqs]

- Crane vendors experienced relatively stable market demand

"I think that the sentiment was already relatively positive in 2025." [MIAS]

PROJECTS BUSINESS MARKET CAN BE LUMPY

- In general, the MHE projects business can be lumpy with many smaller project and then some very large projects and the large projects can often pivot a bad year into an excellent year (and vice versa)

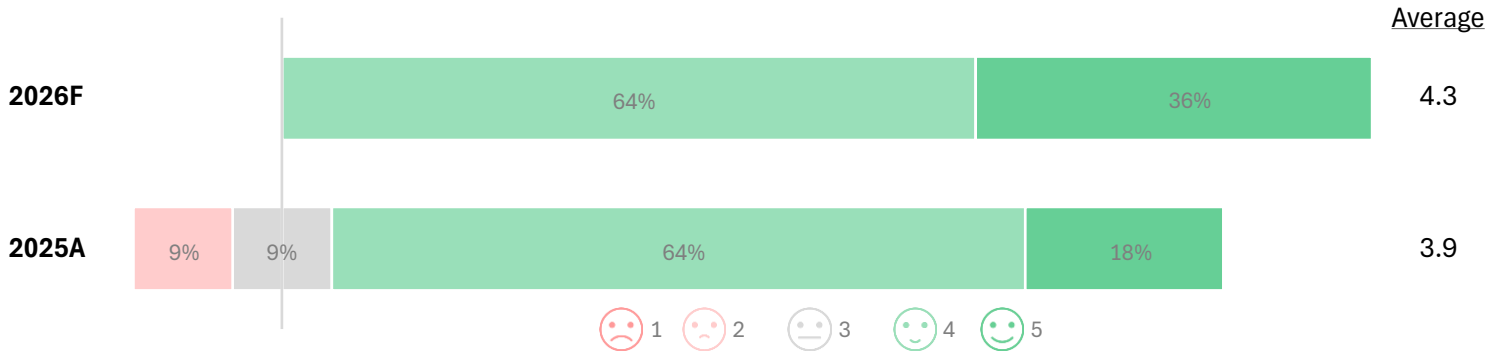
"In terms of the whole company, 2026 will be the best year in our history. But we see that 2027 will be a struggle again. This project business can be lumpy." [Anonymous]

- The relatively nascent nature of the 2D pallet shuttle market segment means this can be lumpier than the overall MHE projects space

"Most 2D shuttle projects are lumpy. Some are very, very large, and those test you as a vendor. That's where you find out who can really deliver." [Geek+]

STIQs SENTIMENT TRACKER INDICATES SHORT TERM OPTIMISM FOR THE ENTIRE PALLET ASRS SECTOR, BUT LONGER-TERM UNCERTAINTY LIKELY TO REMAIN

GLOBAL PALLET ASRS MARKET SENTIMENT 2025A AND 2026F



Source: STIQ Ltd Research & Analysis

OPTIMISTIC SENTIMENT FOR 2026

- Interviews for this report were conducted in 3Q26
- STIQs pallet ASRS sentiment tracker for the sector highlighted a largely positive outcome in 2025 with very few respondents indicating negative growth
- The sentiment for the full year 2026 was overall positive across vendor and integrator segments interviewed for this report
- It is notable there was little difference in the optimism between vendors of 2D shuttles and cranes

2027, CONTINUED UNCERTAINTY (IS CERTAIN)

- Overall, interview suggest there will be continued uncertainty in 2027
- A few vendors appear to be well placed for 2027 while plenty of interviewees reserved judgement based on the degree of uncertainty and volatility in the market

"2027 is expected to be another year with very high turnover, driven by the increasing scale and complexity of projects." [Eurofork]

"We have several projects lined up for 2027, from a few 100 to 10,000 positions, with retailers, 3PLs and manufacturers." [Mytra]

- Some European players view the 2027 market as potentially challenging

"We see less interesting projects in the pipeline." [WDX]

- While 2026 may be a great revenue year, there is some concern about order intake and revenue realization in 2027

"We see that the market is much lower in 2026 for order intake. In the last two months a first sign that less is happening in the market is that assembly companies are calling us and asking for some work for end of Sep, Oct… which is never a good sign." [Anonymous]

THE US MARKET IS DRIVING OVERALL SECTOR GROWTH. OTHER GEOGRAPHIES EXPERIENCING UNEVEN GROWTH WITH SOME CONCERNS FOR 2027 REVENUE

IRAN WAR AFFECTING 2026 MARKET

- Early growth in 2026 was disrupted by the war in Iran

"There was a little slow down of the market at the beginning of 2026. It started very well, then a couple of months before summer business grew a lot and now we are developing a lot of projects. We closed important projects and the forecast is to close many more projects by the end of the year." [Automha]

"I think 2026, is going to be good. But there's no growth, especially because we saw two projects delayed because of the war in Iran." [Logiqs]

- Projects in the Middle East region were affected due to delays of incoming shipments with revenue likely pushed into 2027

"2026 won't be top of the scale because some projects are getting a bit pushed when it comes to incoming shipments. We would not finish and hand over and close the books by the end of this year. And a lot of these projects got signed on in the last 1.5 months so those will push into next year." [Acme]

US: UNCERTAINTY FROM TARIFFS REMAINS

- While tariffs remain as an issue, a degree of 'tariff fatigue' appears to have crept in

"I think generally the economy is good. There is some uncertainty with the tariffs, but our solution is fairly unique. Only a handful of companies can deliver what we do and most of them are not in the US." [MIAS]

- Customers are increasingly coming back to investing despite tariffs – however, upcoming mid-terms are likely to add to the general disruption

"I think that there has been an investment backlog for almost 2 years. First companies, waited until the elections were over to invest again. So not much has happened in 2023 and beginning of 2024. Then we had the elections and the tariff situation started, so companies again didn't invest because of the uncertainty. I think we just hit a point where companies are like, okay, we have to act now." [MIAS]

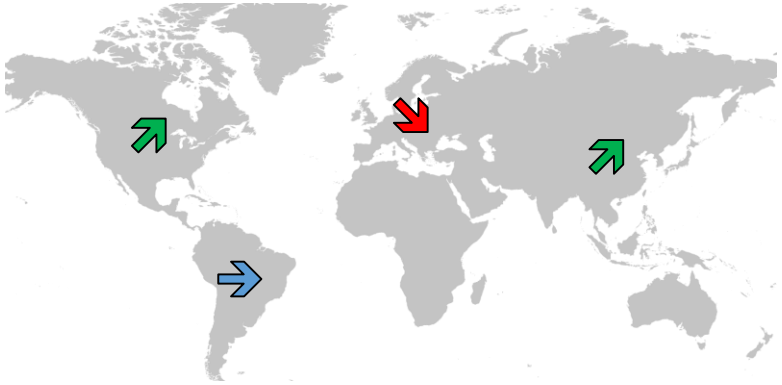
US HEALTHY GROWTH, EU SLOWER

- The US market continues to drive a significant degree of growth with some slowdown or lack of growth in Europe

"The European economy in the last 1-2 years has not been great. The investment climate and sentiment is not super good. In that regard, the US has been having a high potential. On the other hand, the small deals, you sometimes get them, the European deals... you can go against the stream and still create business if even the climate is difficult." [MOVU Robotics]

"Our pipeline is way ahead of where we were projecting in terms of its scale. The US, we've got existing customers that are doing more projects with us, and we're landing new customers as well. We're ahead of our revenue targets and booking targets in both regions." [Spacemaker Systems]

GLOBAL PALLET ASRS MARKET GROWTH



Key: Growth Decline Stable

Source: STIQ Ltd Research & Analysis, Map (Source)

GOVERNMENT GRANTS BOOSTING GROWTH

- Government grants are mentioned increasingly frequently

"There are many countries where there are incentives from the government and the business is growing a lot because also due mostly because to a change inside the needs of the market. Also because when there was Covid, there was a contraction of the market, but after that, companies weren't able to find people. Companies in some sectors, 3PL, large scale retail, F&B, frozen, etc. grew a lot in a short time and they needed automation a lot. So, our industry is affected by geopolitical circumstances, of course." [Automha]

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THE STACKER CRANE MARKET IS EXPERIENCING STABLE AVERAGE LONGER-TERM GROWTH WITH SOME LEVEL OF VOLATILITY OFTEN DUE TO REVENUE RECOGNITION

STACKER CRANE MARKET GROWTH

- Interviews suggest stacker crane growth is relatively stable over the longer term while revenue often varies significantly from one year to another
- Covid catalysed growth in the global MHE sector with a dip in the post-Covid period which appears to be returning to a new normal

"There was strong growth during Covid in our industry, with a considerable dip after, but now we are experiencing strong growth again, especially in North America." [MIAS]

LESS RACKING WITH STACKER CRANES

- One of the advantages of cranes (versus 2D shuttles) can be their relatively smaller proportion of racking/ steel

"Racking is less complex with stacker cranes. Your rack will be more expensive for a 2D shuttle system than it is for a stacker crane system." [MIAS]

CRANE + 2D COMPLEMENTARY MARKET

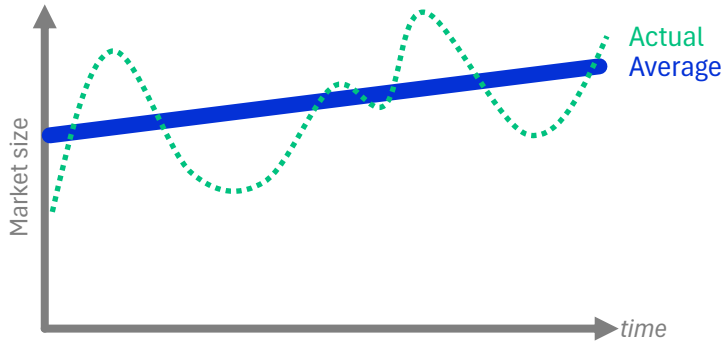
- While the 2D shuttle is currently on trend, the most likely longer-term development is cranes and 2D shuttles will remain complementary

"In the end cranes and carriers will be complementary. If you have some really fast moving SKUs you can use crane systems. they're really good. If you have more stock, then a carrier system is much more economic. Right now, the world is exploring what's the best mix of it." [Logiqs]

"2D shuttles have competition from stacker cranes. But most of the time we win those projects with our Mother-Child system unless a company do stacker crane + shuttle. If it's a small warehouses where you can have only one lane for a crane, sometimes it makes sense to buy a stacker crane. But if you have more channels for movers and more SKUs, 2D shuttles win." [WDX]

"I see more of the market maybe going to the 2D shuttle just because it's newer. It's emerging slowly but surely and it's being proven in the market. Now you have the ability to fly customers to sites in the US, where this has been verified to meet our safety requirements. I do see a little bit of the market shifting to the 2D shuttle. But I will say, again, that there are use cases for a crane system that I don't think, right now, a 2D shuttle can fulfill." [Equipment Depot]

STABLE LONGER-TERM STACKER CRANE MARKET GROWTH (ILLUSTRATIVE ONLY)



Source: STIQ Ltd Research & Analysis

STACKER CRANES ARE MATURE AND RELIABLE SYSTEMS TYPICALLY DEPLOYED IN GREENFIELD HIGHBAY WAREHOUSES

STACKER CRANES, INCUMBENT ASRS SYSTEMS

- Stacker cranes have been around for 50+ years and are the tried & tested technology and often highly reliable but can be more suitable for very stable throughput requirements

"The pallet stacker crane solutions is a conventional solution which is quite reliable with more than 30 years history. It's suitable for large SKUs or large varieties and large volumes. It can get access to any pallet of the warehouse. But 2D shuttle solutions are quite dense or compact compared to cranes. Normally cranes are suitable for large volume, but low varieties or low SKUs." [Deliecn]

"The stacker crane is used when you require a high level of selectivity and a fixed throughput over a period of time. When you're able to say that, okay, I find my throughput requirement is going to be X for Y number of years, and that's not going to change. Then you can lock in the stacker crane." [Acme]

"Stacker cranes are still very good and very quick. They can be a little bit cheaper to buy for the same number of locations. If you have deep channels and low amounts of SKUs, it can be really beneficial with a crane. However, If you are then going to the other extreme where you've got a lot of different SKUs and don't want to go so deep on the channels, maybe only 2-4 deep, that will push you towards a 2D shuttle. Because you've got a lot of flexibility in how you deal with different SKUs and sequencing, etc. It depends on the operation and what they're doing. A large FMCG producing a couple of different SKUs might still see value in a stacker crane, whereas someone like a 3PL might see more value in a 2D shuttle." [Korber Supply Chain]

CRANE END MARKETS, BUILDING HEIGHT

- Stacker crane end markets tend to be defined by the height of buildings

"We have three main markets. They are food, retail, and automotive. Typically, greenfields. We also have a lot of retrofits as many cranes are now 20+ years old. In the last few years, a lot of companies approached us and want to replace their old stacker cranes. Especially in freezer environments. I don't think we have that much competition there with 2D shuttles yet. These freezer buildings are often very tall and go up to 35-40m." [MIAS]

- The stacker crane continue to be more competitive in higher buildings

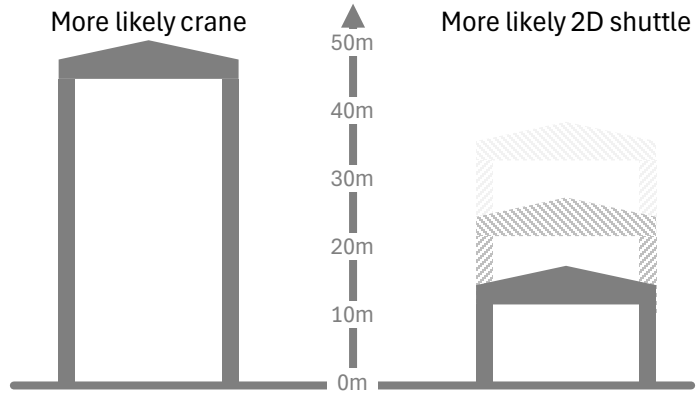
"We don't quote against cranes too often and that's because people don't see the ability at the minute for a 2D shuttle to be able to do what a crane can do. Some of that is that break point in efficiency in terms of the height of the building as well." [Spacemaker Systems]

"Our experience is when the warehouse height is above 25meters, then cranes are very cost competitive. But if it is below 20 meters, you can see that the cost competitiveness of 2D shuttle is really good." [Deliecn]

- While most crane buildings are 30-40m high, there is plenty of lower cranes even in buildings as low as 10m's

"The most common crane projects are between 25-45m tall. There's still a few which are between 10-20m." [Swisslog]

CRANES REMAIN MORE SUITABLE FOR HIGHER BUILDINGS (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

- However, some 2D shuttle vendors suggest they compete against crane vendors in as much as 50% of projects

"In the beginning, we always competed against cranes because no one knew what 2D shuttles were. 3 years ago, we had to explain how it works. Today everyone know what it is and we see more and more that 2D shuttles are requested in RFQs. In 50% of the cases we compete against cranes or where it's kind of agnostic. We also see sites that, if you don't have 30-40m height in a rectangular building, greenfields, you can forget about stacker cranes. That's the market that we serve. Same for Mother-Child shuttles... you can have low buildings, but you need rectangular buildings and long shaped, which we don't need with a 2D shuttle." [MOVU Robotics]

TWO DEEP STACKER CRANES MOST POPULAR. PRODUCTION INFRASTRUCTURE CAN BE AN INHIBITOR FOR NEW ENTRANTS BUT NEW PRODUCTION TECHNIQUES EMERGING

CRANES WITH SATELLITE SHUTTLES

- There are plenty of hybrids in the crane segment with different location depths and solutions with satellite shuttles which may go deeper as well which are often more suitable for very specific niche applications

"We haven't sold ASRS cranes with a shuttle in 2-3 years. But I know for freezer applications you see it more often. The crane itself is going well and we sold quite a lot this year in different applications from chemicals to food manufacturing. It is still the workhorse because for the 2D pallet shuttle the racking is still too expensive. And as long as this is the case, I don't see a development where 2D shuttles replace all pallet ASRSs." [Gebhardt Intralogistics]

CRANE 2-3 DEEP STORAGE

- The most common crane systems are one or two pallet locations deep with a perceived market preference for the two deep system

"I saw some players in this market, they can do 3 deep cranes, but mostly it's double deep. With 2D shuttles you can 5-6-7 deep but if you want to get the middle pallet, you need to move the first 3-4 pallets and then get the middle one. This is why it's suitable for lower SKUs, but larger quantities." [Deliecn]

"Where high selectivity is critical, particularly in single- or double-deep storage, cranes remain an extremely strong solution. In lower-height brownfield facilities, however, other technologies can offer customers greater flexibility." [Swisslog]

CRANE PRODUCTION INFRASTRUCTURE

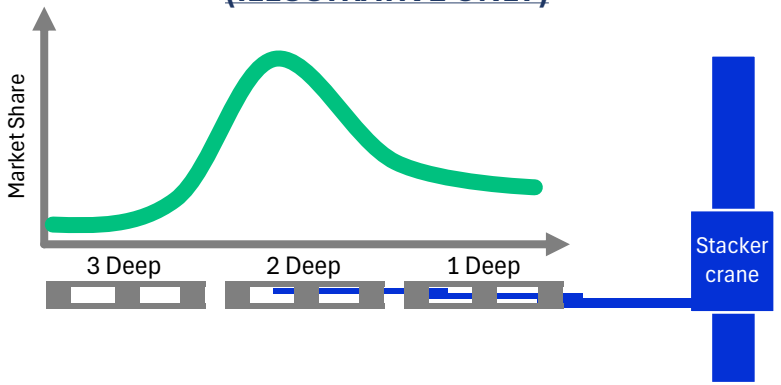
- Barriers to entry in the stacker crane sector include access to suitable production infrastructure with machine shops, welding, etc. and the market is also relatively saturated

"The reason we have decided against producing cranes is it's quite crowded. When we made a decision a few years ago which products we will start with, we decided for ASRS shuttles because we saw more market potential and customers on the market. Because you can have an existing warehouse of 10-12m, and it makes sense for a lot of customers. With a stacker crane you often build the entire warehouse from scratch." [WDX]

- Stacker crane projects can require a high degree of customization and require intermittent significant engineering resources while 2D shuttles can be a more forgiving product to manufacture

"Crane projects have dropped primarily because of us. We are slowly diverting customers to the 2D shuttle. There's a lot of heavy machining of the components required for the stacker crane, we used to outsource that. And then we would do the final assembly and the commissioning in-house. And even testing was a headache. It was not a profitable line of business. It was something we had to do to be relevant. We started pushing the 2D shuttle because you don't have to go back to the drawing board every time. Every single step of a crane project is unique and you have to engineer the whole thing. The 2D shuttle is the same component and is a lot easier for us to deliver a project without having to go into the heavy engineering side of a stacker crane." [Anonymous]

STACKER CRANE PALLET DEPTH POPULARITY (ILLUSTRATIVE ONLY)



Source: STIQ Ltd Research & Analysis

- Some vendors have introduced innovative production concepts to reduce the requirement for production facilities, such as welding, etc.

"Cranes is growing. In the past we bought in the majority of our cranes. Now it's 50-50 own produced. We have a new crane design which is not welded. This is a good concept for us. When you look at others they all originate in some big industrial conglomerates and they have big welding robots and paint jobs and stuff like that and we didn't make that investment because it wouldn't pay off. Now we have a new concept where we don't need to weld and customers really like it because you can also change the rail after a few years if you have to. We sold quite a lot this year. For us it's growing in total for sure." [Gebhardt Intralogistics]

THE MOTHER-CHILD SHUTTLE OVERLAPS WITH 2D SHUTTLE BUT LIKELY TO REMAIN AS IT IS A SUITABLE PRODUCT FOR NICHE APPLICATIONS

STABLE MARKET FOR MOTHER-CHILD SHUTTLE

- The Mother-Child market is smaller than the crane market but appears to remain relatively resilient

"Mother-child shuttle demand has remained relatively stable. However, in terms of overall volume, cranes continue to represent a much larger part of the market." [Swisslog]

MOTHER-CHILD WILL REMAIN ON THE MARKET

- Interviews suggest the Mother-Child shuttle has held and will retain its niche position in the market despite overlapping somewhat with the 2D shuttle

"2D shuttle technology is growing and expanding into some applications traditionally served by mother-child shuttles. But this isn't about one technology replacing another. For applications with sufficiently high throughput, mother-child remains a strong and relatively simple solution. Ultimately, cranes, mother-child and 2D shuttles each have their place, depending on the customer's requirements." [Swisslog]

"Using the 2D shuttle in single aisle is not a very good idea. Or at least an expensive idea. In one aisle we still go for the Mother-Child version because in the end it's cheaper and the throughput is higher. We have sold several in Scandinavia as a production buffer, as a link between production and dispatch. There's a small area where it is a good product. In that area there's no competition for it from my perspective." [Gebhardt Intralogistics]

"It's always about the layout and the throughput. And then based on that, you calculate which is the better solution. Now we have a simulation tool for both 2D and Mother-Child shuttles. In the simulation it shows us which solution is better. But there are projects, for sure, where you can offer both. We do not see the Mother-Child market threatened by the 2D shuttle." [WDX]

SUITABILITY BASED ON DEEP DATA ANALYSIS

- Identifying the most suitable solution or system often boils down to advanced data analysis and understanding the customer requirement, facility, etc.

"We find that applications can be suitable for cranes, but customers prefer a 2D shuttle solution. Sometimes the 2D solutions is not correct, and the best solution is a Mother-Child. It depends on mostly on throughput requirements. But also in that case, because a lot of competitors doesn't have the Mother-Child solution and produce 2D shuttles, they also push a lot for 2D shuttles." [Automha]

"I would say you need a throughput of 40 pallets per hour in and out to automate with a Mother-Child shuttle. If the layout is quite simple then the Mother-Child solution and you need higher throughput, this is a good solution for that. Why we add 2D shuttle is because for some different layouts sometimes a 2D shuttle makes more sense." [WDX]

MOTHER-CHILD PALLET SHUTTLE SOLUTIONS LIKELY TO REMAIN IN THE MARKET

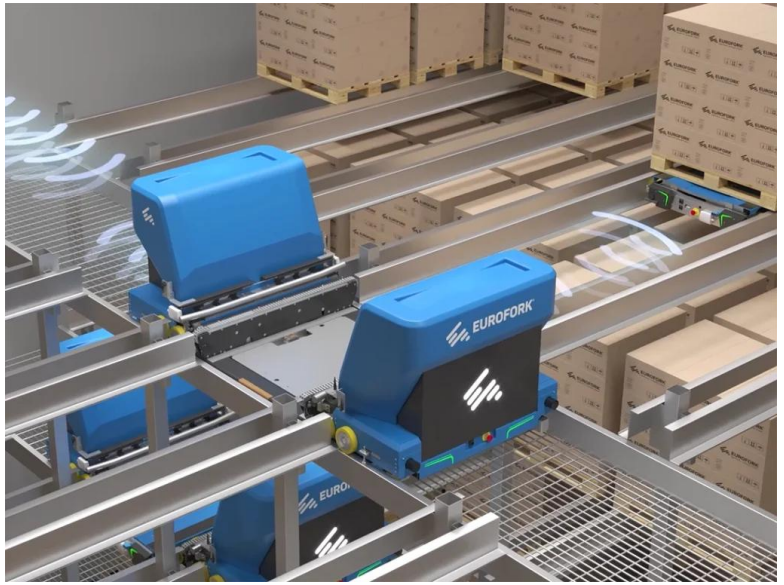


Image source: Eurofork

THE 1D PALLET SHUTTLE MAY BE VIEWED AS ENTRY LEVEL HYBRID AUTOMATION FOCUSED ON DENSITY. NOT COMPETING WITH OTHER PALLET ASRS SOLUTIONS

Pallet Automation 2026
Published by STIQ Ltd
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1D SHUTTLE, FIRST AUTOMATION EQUIPMENT

- Customers for 1D shuttles can be smaller companies with improved density requirements that may lack incentives for full automation

"Generally speaking, the types of customers we see for 1D shuttles tend to be smaller. They tend to be more SME-type businesses. The 2D market seems to be the bigger players that have got more investment capability and more experience with automation." [Spacemaker Systems]

"The 1D shuttle and the 2D shuttle are not in direct competition with each other. Ultimately, the choice depends on what the customer is looking to achieve, on the level of automation required to achieve the desired performance and the features of the building itself" [Eurofork]

- The 1D shuttle is suitable for lower labor cost countries and where customers are not aiming for full automation

"1D shuttles will always be there. The competition is different. You will see these shuttles remain in lower labor cost markets as well. It's a different market to 2D shuttles and cranes." [Addverb]

"The 1D shuttle is for somebody who's just stepping into some level of automation. They still use a manual forklift to place the shuttle. It's for somebody who just wants higher density. The 1D shuttle is traditionally sold by almost every racking vendor. Any racking integrator is able to supply this system. It's only the aftercare which has to go to a professional. It's very basic automation... the first type of pallet automation that people go to." [Acme]

HEALTHY 1D MARKET

- The 1D market is relatively healthy in volume terms

"The 1D shuttle is a consumer mass market product asset. We sell many 10's of 1D shuttles every month with almost no marketing. This is like a cassette, it goes in, picks up the pallet and comes out." [Acme]

- However, the 1D is largely commoditized and vendors require serious volumes to remain in the business

"There are also some vendors leaving the 1D world and we get requests for shuttles to put into racking of other companies that are not able to support them anymore. They are leaving because there's not enough volumes anymore. We are not heavily promoting these in Europe or US. In India we still sell plenty of them. I also see there's a market for that in Africa as well... but it's different than the market in Europe." [Addverb]

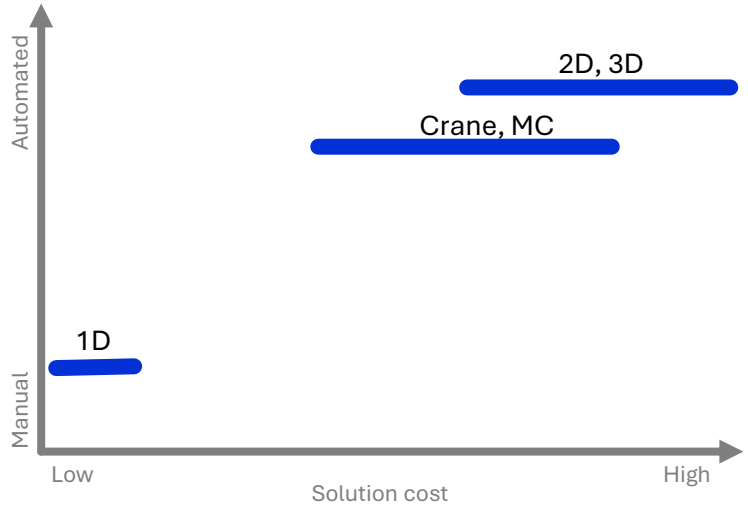
- The 1D shuttle is also partially handled by manual forklift drivers and needs to be robust with associated service & repair capability requirements

"1D shuttles are more sensitive because they are handled manually by forklifts. You have more breakages because they are manually handled. There's more of a replacement or repair market, etc." [Addverb]

DENSITY IS THE GUIDING PRINCIPLE FOR 1D

- Interviews suggest 1D shuttles are deployed for depth

THE 1D PALLET SHUTTLE IS A HYBRID MANUAL/ AUTOMATION SYSTEM



Source: STIQ Ltd Research & Analysis

"I've heard of 1D shuttle systems over 100 deep. We have done up to 70 deep system... I would say 5 deep is the minimum, as the ROI for shallower systems is long and you have alternatives like pushback & drive-in rack available." [Steelking]

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THERE ARE 5 KEY COMPONENTS IN A 2D PALLET SHUTTLE SYSTEM: SHUTTLE, RACKING, PALLET, LIFT AND SOFTWARE

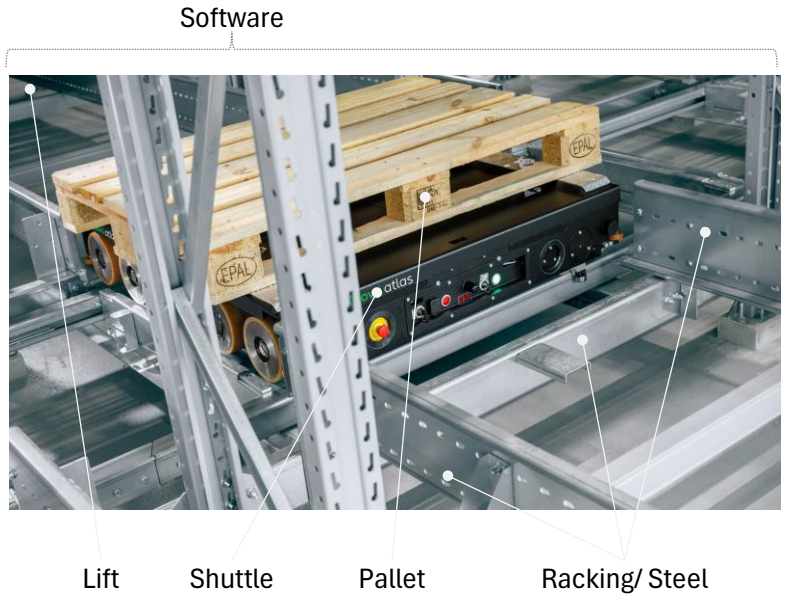
KEY COMPONENTS OF A 2D SHUTTLE

- There are five key components in a 2D pallet shuttle system:
  - Software: The software controls the fleet of individual robots/shuttles and decides where to locate pallets to optimize retrieval performance
  - Shuttle: The shuttle itself often takes the focus as this is the moving part or robot in the system. Reliability of the hardware is critical, but as systems include many robots, there is redundancy if one robot goes down
  - Pallet: The pallet is an integral part of a 2D pallet shuttle system as it can influence operation of a system, for example using wooden pallets that may chip and add debris in front of sensors, etc. It is critical to have good quality pallets in a system
  - Racking: The racking is the infrastructure and having the correct tolerances across many 1,000s or 10,000s of pallet locations is critical as shuttles may wedge in if there are issues with the racking
  - Lift: Lifts move the shuttle between floors (not expanded on in analysis)

COMPONENT SUPPLIERS

- There are plenty of permutations available for buyers of 2D shuttles, from sourcing all components individually to everything from a single company, typically a system integrator

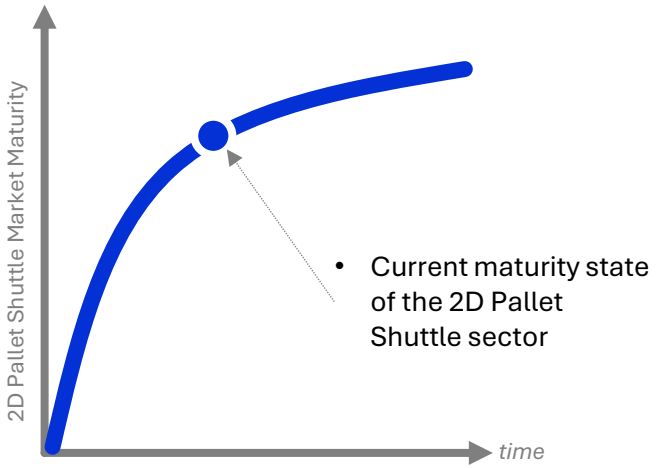
KEY 2D PALLET SHUTTLE SYSTEM COMPONENTS



Source: STIQ Ltd Research & Analysis. Image source: MOVU Robotics

THE 2D SHUTTLE REMAINS RELATIVELY NASCENT TECHNOLOGY WITH PLENTY OF CREATIVITY TO BE UNLEASHED IN APPLICATION AND TECHNOLOGY DEVELOPMENTS

2D PALLET SHUTTLE SYSTEM SECTOR MATURITY



Source: STIQ Ltd Research & Analysis

NASCENT TECH WITH MORE INNOVATION

- Interviews suggest 2D pallet shuttle technology and applications remain relatively nascent with plenty of ongoing software and hardware developments, including building at height and more

"We are developing faster vertical transporters. Normally, a vertical transporter goes 1m/s. We developed one that goes 1.5m/s. A vertical transporters like that is too pricey for a system of 16 meters high. But at 42 meters high, it's really economic now." [Logiqs]

2D PALLET SHUTTLE MOVING TO A 3D OPTION?

- Few vendors currently provide a true 3D shuttle with the majority using 2D + shuttle lifts to move between floors

"Our bots move in 3 dimensions, climb on their own. There are no elevators or cranes. We can handle many types of material flow operations - pallets, cases, and eaches. People will compare us to pallet shuttles and cranes, but we replace both we think." [Mytra]

- The primary issue appears to be related to racking tolerances and associated potential costs rather than shuttle technology

"I just don't know if racking can give you the tolerances required for the 2D shuttle to climb as well. I think achieving the required racking tolerance is going to be very expensive." [Moffett]

STANDARDIZED 2D SHUTTLE RACKING

- Racking suppliers are also trying to develop and steer vendors towards adopting standardized features, sizing, etc. to improve delivery lead times and the cost of steel

"We specifically go into the design interface program if we get RFQs requested by a new shuttle supplier or SI. We enter into a design phase. We have a standard platform with, let's say 90% of the components are standard. And the last 10% is the interface for the specific application. That works very well because it helps us be faster to the market than we used to be. Normally we would take 6-9 months to have a design ready. Now we're much faster." [NEDCON]

EXPERIMENTATION OF 2D SHUTTLE USE CASES

- System integrators are also exploring new use cases with this new technology

"Traditional crane solutions... I won't say it's limited but has its purpose. It's primarily just storage. It's not about how can we use this in different ways or feed different applications. The flexibility of the 2D shuttle... we have a lift that connects us to 100% of the inventory. You've just got a lot more options in how you could potentially design a solution. And the options are obviously not all known at the moment. We'll continue to look for unique ways to use these solutions in the coming years." [DCS]

END-CUSTOMERS DRIVING EXPERIMENTATION

- Expansive and creative customers are assisting in the evolution of new applications

"Customers come with ideas and they ask 'Can your shuttle do all this pickings and things?'" [Zikoo]

- Cross docking appears to be a relatively frequently recurring end-customer request

"We are seeing a growing number of requests for cross-docking applications involving 2D shuttles. This appears to be an emerging trend, with increasing interest coming directly from customers." [Eurofork]

"There are also things that we're doing in the US which is throughput forward... small pilot locations, a lot of shuttles. And it's a cross-docking facility for a large ecom player." [Rainbow Dynamics]

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THE 2D PALLET SHUTTLE MARKET IS SUPER POPULAR AND THE TECHNOLOGY APPEARS TO HAVE OPENED UP A WHITE SPACE AND IS INFLECTING

SIGNIFICANT POPULARITY OF 2D SHUTTLES

- 2D shuttles are rapidly growing in popularity among end customers

"2D pallet shuttles have been around for a few years, but they definitely are increasing in popularity pretty, pretty rapidly in the last year or two, for sure." [DCS]

"I would say the 2D pallet interest has definitely grown a lot since I joined 5 years ago." [Burns & McDonnell]

"2D pallet shuttles are super popular now for sure." [Gebhardt Intralogistics]

- The market erupted a few years ago and now there are plenty of vendors around

"About 2 years ago the 2D shuttle market kind of exploded and everybody jumped on it... European suppliers, but also a lot of Chinese suppliers also now have solutions in that area." [NEDCON]

RACKING MANUFACTURERS ALSO NOTICING

- The relatively high proportion of racking in 2D shuttle projects has had a positive effect for racking vendors

"We are seeing more and more market demand for shuttle racks versus a traditional drive-in rack. Because shuttle systems are stiffer. It has beams at all levels." [Steelking]

- But while there is serious business in 2D shuttles, it seems some forecasts may have been overly optimistic

"The 2D shuttle projects are not growing as fast as we thought they would, but it's coming. We thought it would be a lot more now. I always use the analogy from a hype going to a trend and the trend doesn't go as fast as the hype." [NEDCON]

2D HAS OPENED A NEW MHE WHITE SPACE

- It would appear the 2D market is inflecting

"Five years ago, a lot of companies didn't know exactly what this carrier technology was. Crane technology has been around for 30 years and the big integrators were all focusing on that and they liked it, because of lower risks. Now the market is really turning around, and we're doubling in size every year. We're also noticing bigger and bigger projects in the market." [Logiqs]

- The 2D shuttle has opened a white space

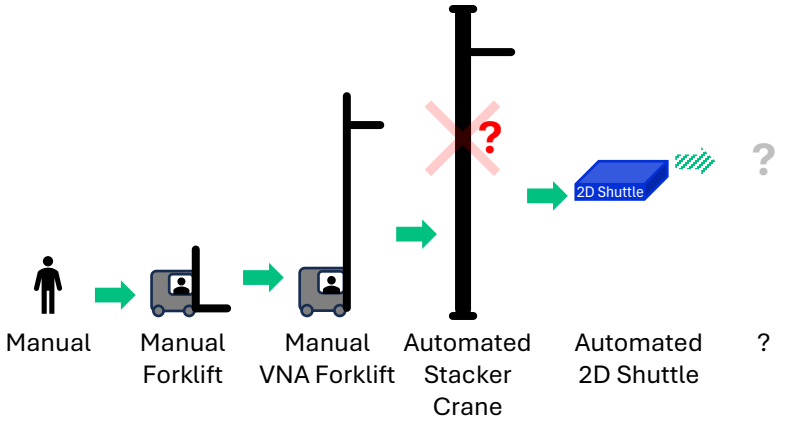
"From my experience, it's quite clear that the 2D roaming shuttle has opened new doors to automation. Normally what you used to hear is you go from forklift trucks to maybe a VNA to maybe a crane and now, maybe the 2D shuttle is next as a kind of evolution. I wouldn't say you go from forklift to a 2D shuttle in every case now. But it's an easier jump because everyone make these technologies seem simpler." [Swisslog]

POPULARITY OF 2D SHOWS IN SALES PIPES

- Sales pipelines have expanded rapidly for many 2D shuttle vendors

"We just launched our 2D shuttle last year and we've already signed 5 projects." [Anonymous]

MATERIAL HANDLING EQUIPMENT EVOLUTION (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

"At the time when we launched our new 2D shuttle we had 3 projects in hand and in pipeline there were 10 projects. So many proposals for cranes were converted into 2D shuttle... that was a breakthrough. Last year we completed more than 13-14 projects which are in the commissioning phase right now." [Anonymous]

"We have implemented only 3-4 projects, but we have sold probably closer to 20. So you can see a lot of the projects are actually coming and they're all 2D driven. If you look at my prospect list fort 2026, I would say 70% of the volume is either 2D shuttle or has 2D in it." [Anonymous]

THE 2D SHUTTLE INCREASINGLY BEING REQUESTED AND FAVORED BY CUSTOMERS. MARKET PUSH NOW REPLACED BY A MARKET PULL FACTOR

CUSTOMERS REQUESTING 2D SHUTTLES

- Interviews suggest plenty of end customers request the 2D pallet shuttle for projects and are often adamant this is the technology they wish to use, in preference of any legacy solution

"Customers are sometimes really explicit 'We want to have 2D shuttles. We don't want to have anything else.' And that's when integrators who don't have experience with shuttlescome to us or to other suppliers and say 'Okay, we have this client. We didn't do shuttles before, but they say they just want to have a shuttle. Help us.'" [ZS Robotics]

- Such 2D requests are also mirrored in RFQs and RFIs

"The 2D shuttle is very special machine. Everybody wants this now. All RFQs and RFIs are going through this machine. I mean, the intralogistics market is going through a profound transformation. Customers need modularity and scalability. Solutions such as the 2D shuttle are extremely attractive to customers and they are asking for a 2D shuttle." [Automha]

- Even some customers that may perhaps not have gone for a relatively nascent technology are requesting the 2D shuttle

"We have a client that is sold on the 2D shuttle. This is a defence contractor... you think about those types of industries that never want to change, they are built on predictability and ensuring the outcome... and they're like we got to have this. There's a lot of demand right now, I can tell you that." [Burns & McDonnell]

2D PALLET SHUTTLES, FROM HYPE TO TREND

- The 2D pallet shuttle is no longer a hype and has moved into the serious business realm in a relatively short period of time

"2D pallet shuttles was really a hype. But now it becomes a trend. Now it's really serious business. And now there are serious projects around." [NEDCON]

- Interviews suggest the push to market has been replaced by a customer pull factor

"For the 2D shuttle. It's no longer a push to the market strategy. It's really the market is pulling the technology from vendors. So pushing the technology became a technology pull. And that's visible as out of 10 customers, 9 are asking for 2D shuttle now, because everyone wants that." [Swisslog]

2D SHUTTLE IS 'THE NEW KID ON THE BLOCK'

- The 2D shuttle has quickly caught the imagination of many buyers

"The general feeling I get in the market is that shuttles are a little bit the new hot kid on the block. So it's 20% already a warmed-up market... but still it's a new solution. Many clients now are looking at shuttles, and they explicitly say... 'We don't want cranes, we want to have shuttles.' Which is not, by definition, the best approach to look at things, because cranes do have advantages and there are certain cases where these can be more suitable." [ZS Robotics]

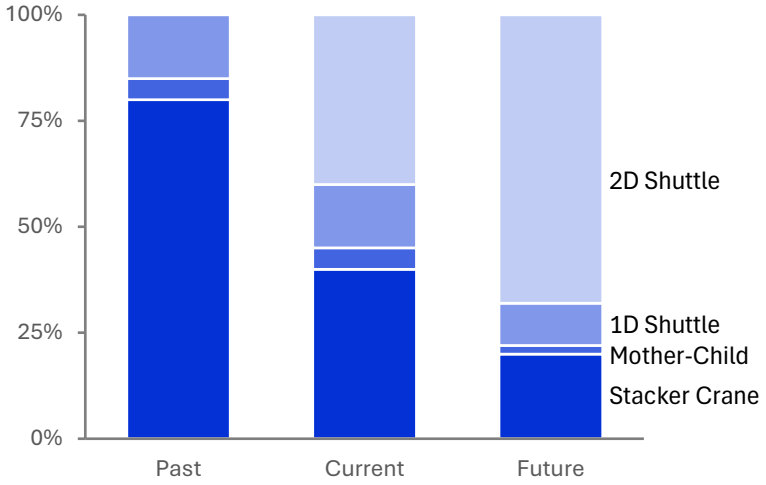
THE FASHIONABLE 2D SHUTTLE



Image source: Gemini, STIQ Ltd prompt

THE POPULARITY OF 2D SHUTTLE SYSTEMS IS LIKELY TO PIVOT THESE SYSTEMS INTO A DOMINANT MARKET POSITION IN THE MEDIUM- TO LONG-TERM

LIKELY FUTURE SCENARIO FOR PALLET ASRS SECTOR (ILLUSTRATIVE ONLY)



Source: STIQ Ltd Research & Analysis

MARKET SHIFTING TOWARDS THE 2D SHUTTLE

- The sentiment among vendors appears to be that the pallet ASRS market is inevitably shifting towards the 2D shuttle
- A similar sentiment is suggested by vendors of both Mother-Child shuttles and cranes

"We still sell mother-child shuttles, but I think between 70-80% of this market in the future will be 2D shuttle systems. There will be still a niche for cranes and the mother-child shuttle. They're still a bit faster than the 2D shuttle, but I think with the management systems improving... I don't see too much space for cranes and mother-child." [Addverb]

2D OFFERS FLEXIBILITY & SCALABILITY

- Primary advantages of the 2D pallet shuttle vs other ASRSs include scalability and flexibility

"I think the future is predominantly going to be the 2D pallet shuttle because this gives you the flexibility of starting off with a low throughput with the ability to slowly ramping up and increasing your throughput. In terms of CapEx, I see 2D and cranes almost at the same level because in one case you're paying more on the stacker crane, in the other you're paying more on racking. It's more capital intensive when it comes to 2D racking, but at the same time it gives you the flexibility which you do not have with a crane." [Acme]

NICHE APPLICATIONS TO REMAIN FOR CRANES

- While most of the market is thought to pivot to the 2D shuttle, niche applications are likely to remain for cranes and Mother-Child shuttles

"The future is not for crane... but, in some application the crane will remain the only solution. If we're talking about F&B, frozen, 3PL, the Mother-Child is perhaps the best solution if you have high throughput requirements. And the 2D shuttle, if you not have the highest throughput demands, is the best solution." [Automha]

THE AVERAGE SIZE OF 2D PROJECTS GROWING

- In combination with increasing demand, the average size of projects is also growing (at least in terms of the number of robots)

"We are experiencing strong growth, with project volumes increasing year after year. This is being driven by the growing scale of automation projects and by collaboration with leading industry players. The number of shuttles required per project is also steadily increasing." [Eurofork]

OVERWHELMING MARKET DRIVERS PUSHING THE 2D SHUTTLE MARKET SEGMENT. BUT INHIBITORS MAY SLOW DOWN GROWTH IN THE IMMEDIATE FUTURE

CUSTOMER AWARENESS IS A KEY DRIVER

- Customer awareness of the 2D pallet shuttle is increasingly creating a market pull
- Part of this popularity is mirrored by the 2D shuttle in how the G2P Solutions sector evolved from shuttles and mini-loads to far more flexible and scalable solutions
- This also includes a degree of 'future proofing' operations for users as adding more robots can improve performance of a system as a customer grows
- While the 2D shuttle provides increased flexibility and scalability, it also offers improved storage density, an increasingly important driver for warehouse operators
- The primary base technology driver for the evolution of the 2D pallet shuttle form factor appears to have been improved battery performance

BUT KEY 2D SHUTTLE INHIBITORS REMAIN

- While market drivers outweigh inhibitors, there are important obstacles for market participants, including cost and pallet quality
- 2D projects can be more costly than other technologies, often due to the higher proportion of racking required, not because of the 2D shuttle technology itself
- End customers have to operate with higher quality standard pallets to use any type of automation, but this can be an obstacle in 2D pallet shuttle projects where the cost of the system is exacerbated by the potential additional cost of changing to a higher quality pallet inventory

PRIMARY MARKET DRIVERS FOR THE EMERGENCE OF THE 2D SHUTTLE

Market	Market Driver	Description	Impact
2D Pallet Shuttle	Customer awareness	• Customers are increasingly aware of new technology developments and may have focused on improving case & each fulfilment automation already, now moving on to pallet storage from other pallet ASRSs	▲
	Flexibility & Scalability	• Flexibility to scale up/down a solution is increasingly demanded by the market, not locking in your throughput for the next 10-20 years • This also includes redundancy as each shuttle can reach every location	▲
	Redundancy	• A 2D shuttle system can reach any pallet even if one or two shuttles go down. In a crane system, an entire aisle is inaccessible if it goes down whereas a 2D system can continue operating at a high efficiency	▲
	Density	• 2D shuttles offer superior density compared to cranes and mother-child solutions (note 1D solutions also offer density, but lack the more advanced functionality, including roaming ability, of the 2D shuttle)	▲
	Technology developments	• Batteries have developed rapidly on the back of EV market developments which has allowed improved form factors, such as the slim 2D (120-125mm)	▲
	Cost	• The cost for 2D pallet shuttle systems remains relatively high compared to other pallet ASRSs partly due to the higher ratio of steel and racking	▼
	Pallet quality	• All automation requires high-quality standard containers incl. pallet quality which remains questionable at many potential customers • Changing to higher quality pallets can be very costly = potential inhibitor	▼

Source: STIQ Ltd Research & Analysis

REDUNDANCY, FLEXIBILITY AND SCALABILITY OF THE 2D SHUTTLE OFTEN MENTIONED AS KEY ADVANTAGES COMPARED TO OTHER PALLET ASRS AND MARKET DRIVERS

THE REDUNDANCY ASPECT

- Redundancy is held up as one of the key advantages of the 2D shuttle

"The main drivers for the popularity of 2D shuttles are scalability and redundancy." [Moffett]

"One of the main things is that you get redundancy with 2D shuttles. If one crane goes down, the entire aisle is down. With the 2D shuttle your throughput would drop, but you could just relocate one of the shuttles to get that particular location covered." [Acme]

"A carrier system offers redundancy. If one carrier is out, another one can instantly take over and continue operating the system." [Logiqs]

MODULARITY, FLEXIBILITY, SCALABILITY

- 2D shuttle modularity mirrors the scalability & flexibility of new G2P Solutions and has become a key selling point for new solutions, including for the 2D pallet shuttle where customers can scale with additional robots to increase throughput

"Some FMCG companies are still saying we want to go for the shuttle because they're seeing the modularity of it. And then if you have a breakdown, then you're only running out and fixing one shuttle versus you're having to taking out a whole aisle. And even with aisle switching, it's quite heavy and quite a job to push out your crane and get it out of the way to access all those SKUs again. An important note is that shuttles still need to be retrieved. which can be tricky and lose operational time too. However, in the heat of the moment, its a few lost locations vs a whole lost aisle." [Korber Supply Chain]

"The market is driven probably partly because it's sexy with a shuttle and partly it is also true that you have a lot of flexibility so you can go from a very low throughput to a very high throughput between just by adding shuttles and lifts if you have to go different levels. And partly it is also about redundancy. We get a lot of requests in brownfields because you can use more corners of the warehouse. You are a bit more flexible with the space above the shipping area, for example, so you can cramp in more pallets in the same footprint." [Addverb]

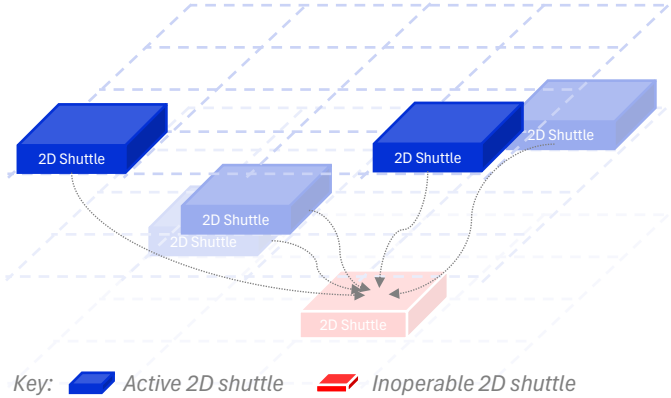
"One of the main benefits of a 2D shuttle system is that it provides maximum capacity from the outset, while allowing customers to expand the installation as their business grows. As sales increase, additional 2D shuttles can be added without having to make the full investment upfront. The key strengths of pallet shuttle systems are their flexibility and scalability." [Mecalux]

2D SHUTTLE FLEXIBILITY PREFERRED BY SIs?

- Cranes may become a more specialist niche solution managed largely by vendors directly as some system integrators may prefer the design flexibility of 2D shuttles

"I think the crane can still make sense. But I don't know that I've experienced a situation where I'm strongly considering a crane in this day and age. Just the flexibility... that's always been a concern for most clients we talked to. And if the crane goes down, then you're stuck until it gets up and running. That's always been a risk and a concern that you just have to deal with as it comes. As we move into the future, I would envision cranes kind of falling out of favor and being replaced with the 2D shuttles." [DCS]

REDUNDANCY IN A 2D PALLET SHUTTLE MULTI-ROBOT FLEET (ILLUSTRATIVE)



Source: STIQ Ltd Research & Analysis

"When we're solutioning, we generally prefer a 2D shuttle system. Shuttle systems are more dense, and they fit better with any shape building. If you have a brownfield and you don't have control of the building shape. And the building might be too long or too short or whatever, a shuttle system usually is easy to design around that. But where a crane is valuable... sometimes we have customers that have payloads that don't fit into a shuttle system. Maybe they're trying to move 3,000 pounds of pallet and that maxes out a shuttle system. Cranes are pretty robust. Typically, cranes handle higher payloads." [Equipment Depot]

2D SHUTTLES OFFER DENSITY ADVANTAGES COMPARED TO OTHER FULLY AUTOMATED PALLET ASRS SYSTEMS

THE DENSITY ASPECT 2D SHUTTLES

- Storage density may be an important aspect for end-customers and the 2D shuttle offers significant density advantages (compared to other full automation systems, not 1D shuttle systems – on par)

"Another aspect is shuttles are great for density. And we can go 2-3 deep, even 12 deep... But with that comes a challenge. If I have a customer with a large amount of SKU variety, unique SKUs and unique lot numbers, I might make the pivot to a crane system because a crane system is 1-2 deep and is easier to access any pallet. With a shuttle system, if I make it 1 or 2 deep, I'm sacrificing density. So there's a formula for when it makes more sense to go with a crane vs. a shuttle system." [Equipment Depot]

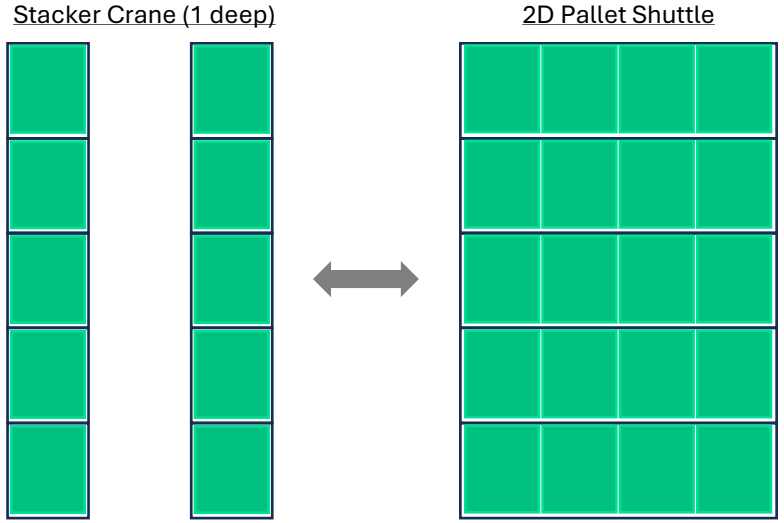
"It's really anything with the number of pallets, if storage density is a play. I don't necessarily see a particular industry with more interest in 2D shuttles. We're looking at a medical supply company that is interested in it... a plant with a warehouse attached, a manufacturing situation. And then situations where a particular facility doesn't have the option to expand or move to a new building, they're looking for ways to get as much storage in their current footprint as they can." [Anonymous]

MULTIPLE VARIABLES DETERMINE SOLUTION

- However, only deep analysis of customer data determines the correct system but there will inevitably be cases where there is a significant overlap and where customers can select from multiple pallet ASRS systems

"It is hard to explain in or just 1-2 sentences. There are a lot of factors we need to consider. The throughput every day, hour, in- & outbound, height & shape of the warehouse. Is it regular or irregular shape? How many SKUs, weight of goods, how many batches... is there a software integration requirement... peak hours, in how many hours orders need to be fulfilled. All these factors need to be analyzed and after that, we'll give the right solution for the customer. Sometimes cranes is better and sometimes we can use the 2D shuttles." [Deliecn]

DENSITY OF PALLET ASRS SYSTEMS (CRANE VS 2D SHUTTLE, SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

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2D PALLET SHUTTLES ARE SOLD WHEREVER THERE ARE PALLETS AND STORAGE APPLICATIONS

WHEREVER THERE ARE PALLETS, REALLY

- Interviews suggest there is demand across industry verticals and wherever pallets are stored and/or managed

"There are no specific sectors that are better or worse for 2D shuttles. Let me give you an example. 2-3 years ago the LI battery for EVs prospered in China and we had a lot of production expansion at that time. A lot of warehouses were built during that time. We got two customers and their products are the same. They materials storage is totally the same. They all produce the raw materials for EV batteries. But one uses the crane solution and the other use the pallet 2D shuttle solution because their production pace and the internal workflow is different." [Deliecn]

"There's still a lot of potential growth for 2D shuttles. The best example we have is our 200 projects and about 120 of them are live. An hours drive from our HQ, we have about 50 sites. It's not the most economic area in the world. It's just like we sell it to everyone. People that are not familiar with automation, people that didn't realize they could use it, they say, oh, well, I need storage obviously, and I run out of space, and I run out of people, and this is accessible to me. We have customers that operate the system with their forklift drivers." [MOVU Robotics]

- There is some shift towards projects in warehouses connected to a production facility

"More than 60% of customers are production companies, but the biggest projects come from 3PL providers. So in numbers, they're smaller, but in volume, they're bigger." [Logiqs]

"A lot of our projects have been tied to production facilities. Using the ASRS to do that transportation of loads between areas and production lines and QC areas, that's been a big benefit and a way we can improve the ROI of our system is it not only doing storage, also a lot of transportation between areas. Being a little bit flexible there that some of that can change your destinations and pick up points as their production facilities change and adapt over time. Docks get expanded or extended, we can add pick up and drop off points there." [Aistorage]

- It also appears customers of all sizes are able to invest in 2D pallet shuttle systems

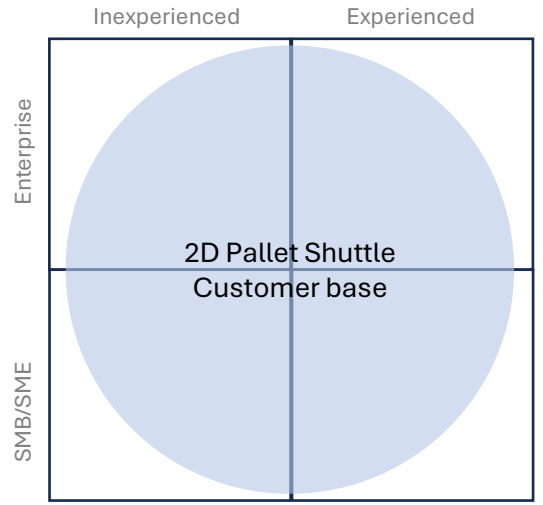
"It's not always about labor cost, it's also about the cost of storage space. So the need is not always about throughput because some customers can handle it with manual forklifts. The need is more about 'okay, we have this warehouse with this storage space, and the current infrastructure provides 3,000 locations, but we expect to grow to 6,000 locations, and then we want to have an automation solution.' Shuttles works very well in this case because the required throughput is limited so you don't need cranes." [ZS Robotics]

EXPERIENCED/NON-EXPERIENCED

- There is no real consensus on customers level of experience of pre-existing automation

"The 2D shuttle customers we're generally working with have had some form of automation in their business already. Maybe not pallet automation, but they've certainly adopted and implemented automation technologies." [Spacemaker Systems]

2D PALLET SHUTTLE CUSTOMER DEMOGRAPHIC



Source: STIQ Ltd Research & Analysis

"Pallet shuttle customers rarely have existing automation. Obviously, we prefer customers who already have some kind of automation. Even simple pallet lanes are sometimes enough for us to make a discussion with them easier." [Anonymous]

INCREASED PREVALENCE FOR 2D SHUTTLES IN TEMPERATURE CONTROLLED ENVIRONMENTS AND AMONG FOOD & BEVERAGE END-CUSTOMERS

TEMPERATURE CONTROLLED ENVIRONMENTS

- The share of temperature controlled customer deployments varies somewhat between vendors

"Cold storage is between 25-50% of our opportunities at the moment." [Spacemaker Systems]

"I would guess about 20% of our work is in temperature-controlled environments, frozen, etc." [ZS Robotics]

"Verticals are very various, so like all kinds of manufacturing, like a pharmaceutical and vehicle parts and chemistry. Some is paper roll. Frozen is less than 10%." [Zikoo]

"About 60% of our projects have been in cold storage. It's also because in cold storage, you have the biggest advantage with a carrier system. You don't want to let people go on the forklift in a cold store. The biggest advantages are in cold store, in terms of energy usage and labor. But we're now also seeing growing demand for ambient applications." [Logiqs]

F&B IS OFTEN QUOTED AS KEY VERTICAL

- F&B is mentioned frequently as a key customer vertical that occasionally also overlaps with CPG/FMCG vertical

"If you ask about the top industries, we have F&B, which is a lot of inquiries. We have grocery, a lot of inquiries, but we also have furniture, which is not the top three, but probably top four. And then you have electronics... wherever you have pallets, really." [ZS Robotics]

"A large proportion of what we are doing is in F&B. Other than that it's 3PL, cold storage and pharma." [Anonymous]

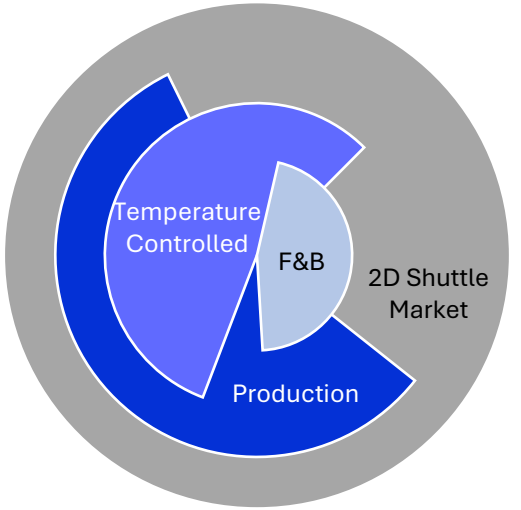
"We have customers in healthcare and F&B and more. We've quoted a lot of F&B, because they value having the ability to access all the data for their SKUs in order to be compliant with FDA regulations." [Equipment Depot]

"Our major customer base at the moment for the 2D shuttle, there's a lot in pharma, cold storage, F&B manufacture, white goods, FMCG. It's a really good spread across different types of verticals." [Spacemaker Systems]

- Some vendors offer a wider range of ASRS systems and see a preference for a particular technology by vertical

"Mother-child systems are commonly used in sectors such as F&B and grocery. The 2D shuttle is a highly versatile solution that is used across multiple industries." [Eurofork]

PREDOMINANT VERTICALS, SECTORS INVESTING IN 2D PALLET SHUTTLES (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

2D SHUTTLES ARE MORE SUITABLE IN BROWNFIELD FACILITIES (THAN A STACKER CRANE), BUT THE SHAPE AND HEIGHT OF A BUILDING IS ALSO AN IMPORTANT CONSIDERATION

HEIGHT & SHAPE OF THE BUILDING, A FACTOR

- 2D shuttles are the go-to option for brownfield facilities, but the ceiling height also needs to be considered

"I would say once you're working in a brownfield, I will almost never run to the crane as an option. If I'm retrofitting an existing facility and if you can't take advantage of the height and go vertical, the crane almost never really pays for itself in my opinion. I would differentiate between greenfield/ brownfield and more to the clear height. There are some municipalities that don't allow high bay storage... plenty of municipalities won't allow for building over 60 feet." [Burns & McDonnell]

"2D shuttles are more favorable for brownfields where you don't have to have a straight line. A crane solution, if you need five aisles and your building is misshapen and you need one aisle that's shorter than the other, it doesn't necessarily make sense. I liken it to almost like a grid-based goods to person, where you can have any kind of shape really you want, and the 2D shuttles can go wherever they need to. They're much better suited for a brownfield, obviously, than a crane-based solution for sure." [DCS]

- The quality of the flooring slab is another factor to be considered

"Brownfield depends on the quality of the floor and what you've already got inside, how tall the building is, etc. A 2D shuttle is a little bit easier to put into a brownfield site. 2D shuttles are easier to adapt to existing buildings, whereas stacker cranes are more rigid." [Korber Supply Chain]

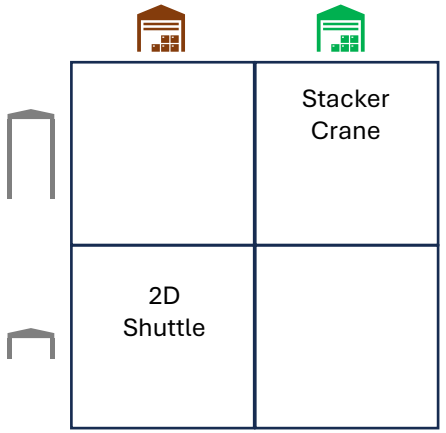
"A lower building is, especially if you have an existing building without a lot of height, then a stacker crane probably isn't the best solution. A 2D shuttle could be a better solution, or an automated VNA could also work. We sold two stacker cranes for pallets at 7m height in 2024, so sometimes you find a place for them. But it's clear that in lower buildings, more and more the pallet shuttle systems will take over." [Toyota Automated Logistics]

2D MAY DOMINATE BROWNFIELD, BUT...

- While 2D shuttles are rocketing in popularity, cranes can be more cost effective in certain facilities and are unlikely to disappear from the market in the short-term

"I think the future for pallet shuttles is in brownfield / existing buildings. The more pallet locations you need for your storage, the more my thoughts are going into the classic stacker crane direction. We have a project in realization phase which is a high-bay warehouse with c.80,000 locations, a huge system. We checked the costs for a 2D pallet shuttle system because the customer said, 'I would like to have a pallet shuttle system, not stacker cranes'. But the price difference for the pallet shuttle system was 50-60% more expensive than the one with cranes. These days... mostly because of the costs, that's where cranes perform." [Toyota Automated Logistics]

PALLET ASRS SUITABILITY BY BROWN-/ GREENFIELD OPPORTUNITY



Source: STIQ Ltd Research & Analysis

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THE BIGGEST 2D SHUTTLE PROJECTS ARE FOUND IN THE US WHERE WAREHOUSES ARE LARGER WHILE THE CHINESE MARKET IS MOST DEVELOPED

Pallet Automation 2026
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DEMAND FOR 2D SHUTTLE ACROSS MARKETS

- Vendors experience demand for the 2D pallet shuttle from across continents

"We're seeing very good demand across both North America and Europe. And there are some inquiries from South America as well." [ZS Robotics]

- More than 50% of 2D pallet shuttle vendors globally are based in China and the market is perceived as most advanced when it comes to awareness of these systems

"In terms of customer awareness of 2D shuttles, I rate Asia first and then Europe and the US last." [Rainbow Dynamics]

THE US MARKET OPPORTUNITY IS BIGGER

- Interviews suggest the US automation investments are continuing apace, especially when compared to Europe

"Especially in the US, there's still very good markets. In Europe it's a little bit flat market, the big projects are there and you can find them... with a magnifying glass. The middle size are okay. Smaller size projects are still pretty good. In the US, it's a lot better. Investments in automation in the US are really very healthy at the moment." [NEDCON]

- Projects in the US market are on average much larger when compared to European project sizes

"A large size US project would be many $10m's worth of racking. You don't see them in Europe. A European large size project is half the size or less. That's a big difference. These bigger size projects... you spend a lot of time on site. I mean, we don't do 10 at a time. I mean a large project would take 1-1.5-2 years on site." [NEDCON]

"US projects are larger compared to European one. The warehouses are just a lot bigger, massive in the US." [MOVU Robotics]

"The biggest orders are coming from the US, no question. But Central Europe is where we're getting good activity now as well." [Anonymous]

US TARIFFS AFFECTING RACKING AS WELL

- While US tariffs have somewhat softened the competitive pressures for domestic automation manufacturers, a price delta advantage appears to remain for imported products

"Tariffs definitely helped us against imports, at least on the hardware cost side. There's a price premium for manufacturing and assembling in the US." [Aistorage]

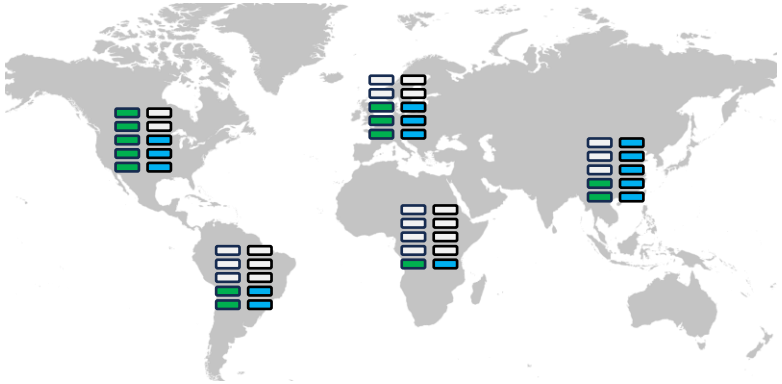
- Tariffs on steel have also disrupted pricing for pallet racking which is a core component in especially 2D pallet shuttle projects

"Because of the tariffs, that's a big challenge.. more companies are trying to now Source more rack in the US. We are seeing that from multiple... I would say almost every month we are speaking to a new integrator who reaches out to us that they would like to start sourcing rack within the US because of the uncertainty with tariffs. But end users also want their rack asap and sea freight takes time." [Steelking]

EUROPEAN MARKET, A NATURAL EXPANSION

- Interestingly some of the North American vendors are expanding into Europe

2D PALLET SHUTTLE OPPORTUNITIES VARY BETWEEN CONTINENTS



Key: Value of opportunities Quantity of opportunities

Source: STIQ Ltd Research & Analysis, Map (Source)

"When we looked at where to expand, Europe is such a dominant market globally. We all know the US has got enormous potential, and it's got enormous capability for investments in automation. But that's followed by the appetite for investment and experience of automation technologies in Europe. For us, a natural expansion of the business is to focus on Europe." [Spacemaker Systems]

CHINESE VENDORS HAVE BENEFITTED FROM DEVELOPING THEIR PRODUCTS IN A HUGE DOMESTIC MARKET AND ARE TAKING LEARNINGS OVERSEAS

CHINA, AN MHE MARKET ON STEROIDS

- While the Chinese 2D pallet shuttle market is huge in terms of projects, the variability of projects can be wider compared to other markets, partly due to the early adoption of the technology and number of vendors

"In China we have the largest deployment with a leading Chinese sports brand. We have 76 shuttles with them. But having said that, we also have a lot of small projects in China, and this is characteristic of the Chinese market in general. In general, European projects are more sizable if you look at storage locations, 20,000 -50,000 pallet locations is mid-size, and then 100,000+ locations is probably bigger projects. In China you can easily find projects with 5-10,000 locations. That's an important project difference in the markets." [ZS Robotics]

CHINESE VENDORS GOING ABROAD

- Chinese vendors have built significant experience in the domestic market and are increasingly focusing on overseas markets

"In terms of project numbers, we are similar to other leading vendors with hundreds of deployments. But some of the focus is regionally in China. Some years ago we started expanding to Japan, South Korea, Singapore, and these different markets. There's a good demand for 2D shuttles overseas." [ZS Robotics]

"Currently about 65% of our output is deployed out of China and 30-35% abroad. Maybe in 2026 this will be more like 60/40." [Zikoo]

"I found that the application of pallet 2D shuttle in China is quite early. And now more and more overseas markets they realize the competitiveness of this shuttle solutions. We start our overseas business from 2024." [Deliecn]

FAILED PROJECTS, FAST LEARNINGS

- There are moves towards using more standardized sizes of shuttles and racking to ensure ease of replacement, but this may lead to a degree of hardware commoditization

"The thinnest 2D shuttle we can go to is 120 mm, but the 125 mm is a little bit of a market standard. This is where we put more development resources now because... to give you an example, last year we did two sites in China where the shuttles from competitors failed. The client kept the racks, but they went to us for new shuttles. For such projects, you want to have something that is in line with the market standards because you can keep the same rack and you can just put in an existing shuttle. We have many standard products, and also non-standard like anti-explosion shuttles..." [ZS Robotics]

- The Chinese market has acted as a useful test bed for vendors to develop their product

"Because we can test a lot of application and fix a lot of problems to make our 2D shuttle more reliable during the using or the project in China. This has in turn accelerated the application of 2D shuttle technology in overseas market as well. Right now, customers from all over the world are coming to China to learn about our 2D shuttle technology." [Deliecn]

CHINESE VENDORS REALISTIC THREAT BUT...

- While Asian vendors may present a significant threat in the market, the higher proportion of racking in these projects may play into selection criteria

"Asian vendors are a realistic threat, but in the end, I think what many forget is the integration with racking, which I believe remains a space that will be dominated by local manufacturers." [MOVU Robotics]

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PLENTY OF SYSTEM INTEGRATORS ARE EVALUATING POTENTIAL 2D PALLET SHUTTLE PARTNERS. RISK MITIGATION IS A KEY DRIVER FOR PARTNERSHIPS

EVALUATION IS OFTEN RISK MITIGATION

- Plenty of system integrators and other types of partners continue to evaluate 2D shuttles, partly because the market is inflecting but also because it remains a relatively new technology

"For us, we're not so focused on who manufactures the rack as long as it meets the specifications of the application. And that it comes at a low risk. Cost is cost, but risk is even more important to manage. So, if we're talking it's coming from China or coming from overseas, it's going to be potentially more risky." [Burns & McDonnell]

"A lot of system integrators are approaching us or have already aligned with somebody else, because they see the same 2D trend. Some of them did not pick up the trend early enough. Now they see the market's asking for it and they sell a lot of 2D pallet-based systems. They need to partner... and that's the same for a lot of system integrators, because most of them don't have a 2D themselves." [Addverb]

- Risk management evaluation means system integrators need to do in depth analysis of both the shuttle and the vendor to ensure they are both reliable

"I think that this is one of the most important points that integrators look at-ok, how easy is your machine to use and how reliable is it? Cost is always a factor, but then they look at the total cost of ownership. How much does it cost in terms of maintenance? How many times does it break down, and do I need to send people on-site? How easily can I fix it, etc." [ZS Robotics]

QUESTIONS FOR VENDORS VARY

- Many system integrator evaluation questions go in-depth on components, lifecycle management, failure management, CE marking, etc.

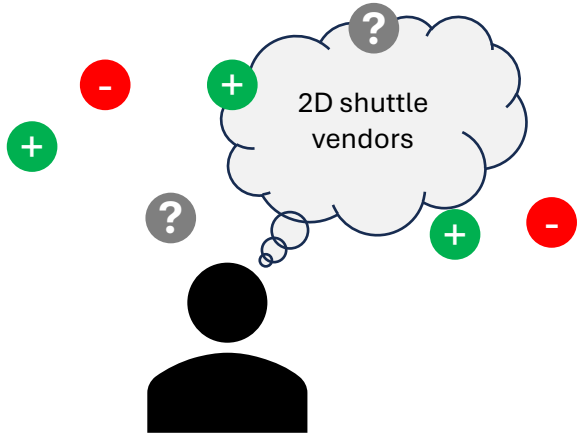
"I just talked to a new integrator...so I got a lot of these questions... reliability. In Europe, of course, CE... they always look at CE conformity, not just the certificates, but they also dig quite deeply also into the components. Not just that whether you have the certificate, but also how do you handle maintenance? How do you handle failures, etc.? They want to see that it really works for the European market. It's definitely number one. The second one, I would say, is on components, spare parts-the availability of spare parts. That's, of course, very important. We are CE-certified and have CE certified projects." [ZS Robotics]

MANY VENDORS SIMILAR, EVALUATION TRICKY

- Vendor evaluation has quickly become a more complex task as there are numerous vendors in the space with no apparent superficial difference

"The 2D technology is important, but we haven't seen truly any kind of groundbreaking differences from one shuttle to the next. There are some things like charging capabilities, the type of batteries they have... this has been a factor on one project. A lot of it is really the experience with a rack supported application, for example. In one project we've got a certain wind gust that we've got to sustain to the level of confidence that one vendor may have deployed in those environments. It's just not as high. They can't point to enough applications to where they've proven that they could truly handle that and do it well." [DCS]

SYSTEM INTEGRATOR EVALUATION CRITERIA AND RISK MITIGATION (ILLUSTRATIVE)



Source: STIQ Ltd Research & Analysis

- Integrators also have to consider the potential strategic advantages of a buy or build it yourself decision

"You always have to consider the make or buy decision. Our focus was always on stacker cranes. With the emerging pallet shuttle technology, mainly lead by a few vendors, we had to decide where to bring in our development capacities. We're still focused on the stacker cranes, because in my opinion, stacker cranes will always have a future, at least in the pallet ASRS market. However, the pallet shuttle systems will find its place. For us, it's easier to work for that with a partner." [Toyota Automated Logistics]

REFERENCE SITES TYPICALLY ALLOW POTENTIAL PARTNERS TO EXPERIENCE A LIVE INSTALLATION AND DISCUSS WITH END CUSTOMERS

REFERENCE VISITS CAN BE EDUCATIONAL

- In general, the reference visit is a key evaluation activity, not only for end-customers, but also for system integrators evaluating new vendors as it allows an overview of a working solution and an opportunity to talk to users

"We're trying to figure out where our 2D sweet spot is. It may be that multiple vendors make sense. We've definitely learned a lot over the last few years. Initially we had 4-5 different options we would look at. As we started doing our research and going to sites, we quickly realized, okay, you haven't done quite as much as you say you have done. You say you've done free standing or rack supported, but you haven't actually done rack supported. We've truly learned who's got the most experience and who can really be trusted to do a large scale project. At the moment, there's two vetted partners that we work with. I'm confident there's probably 3-4 more that have successful live sites, they've got a few lessons learned, they can implement a project. We're definitely open to evaluating more than just the people we're working with currently." [DCS]

"When we picked suppliers, we visited their factories and their reference projects where we could actually see the real working environment. And we were speaking with the user as well... also important for us was the technology. And how the equipment is produced and SLAs." [MGL]

INTEGRATORS LACKING KNOWLEDGE (NOW)

- 2D shuttles remain relatively new technology and there is a degree of education for system integrators and other partners of how they can use this new system

"There is still a significant learning curve for integrators when it comes to 2D shuttle technology, largely because it is a relatively new solution. Understanding not only the system itself but also the underlying technology is becoming increasingly important. As the market continues to grow, the need for technical support and expertise during implementation is also increasing. For us, being part of a global organization as Cascade with a strong local presence provides an opportunity to offer closer support during installation and deployment. This is changing the traditional model, with greater involvement throughout project execution and a stronger focus on ensuring successful integration." [Eurofork]

- This is mirrored by consultants currently evaluating the sector

"2D pallet shuttles are something that's definitely on the rise in terms of customer interest. I've been trying to upskill myself on the sizing of the systems. I've done a number of high level designs for clients where they could take it and use it as a indicative cost for how much the system would be to see if there is a business case. We're now getting into the RFP stage and going out to integrators for firm quotes for this type of technology." [Hatmill]

SYSTEM INTEGRATORS WANT TO ADD VALUE

- System integrators may want to learn as much as possible about the technology and where their value lies, if there is no value in selecting the racking, perhaps this could be better executed by a partner

SYSTEM INTEGRATORS MAINLY ADD VALUE TO SOLUTIONS, LESS WITH RACKING

2D configuration	Racking
• Added value, especially in scenarios where a 2D pallet shuttle is a part of a larger solution • For example, a solution including palletization, wrapping, outbound sequencing in different streams, pick faces, etc.	• Limited added value for a system integrator • Potential for partner to source

Source: STIQ Ltd Research & Analysis

"Some vendors will only do a shuttle and nothing else. And because they'll do a shuttle and nothing else, the onus is on an integrator to bring together all that information and say, well, what else do I need? And as a result, it becomes a little bit more arduous for some people who are trying to figure out how to get into that space. You've got some people that are nervous about this kind of deployment. With these new technologies being the first helps and then showing your expertise. And showing that it has already been done before. Reference sites hold a lot of weight in decisions." [Korber Supply Chain]

SOFT FACTORS ALSO PLAY INTO PARTNERSHIPS. MOST LIKELY SYSTEM INTEGRATORS WILL WANT TO PARTNER WITH MULTIPLE VENDORS TO HAVE OPTIONS

Pallet Automation 2026
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GEOPOLITICS MAY PLAY INTO DECISIONS

- A multiplicity of aspects play into partnering decisions, including experience and, increasingly also, geopolitics

"When I talk about learning a lot recently … we've got a 2D project we're working on right now. We evaluated a vendor for the primary solution because we've worked with them in the past. They fell into the bucket where they didn't have quite the amount of experience of 2D shuttles as we were hoping they would. And then there's always the geopolitical aspects of the world we live in today and some of the unknowns that can sometimes be a little bit risky. These projects are complex enough as it is, and adding the increased tariffs we may need to put on certain items when we're bringing them into the country is just another unnecessary worry. We don't discount Asian vendors entirely. But I would say European is the primary focus at the moment in terms of the vendors we're looking at." [DCS]

2D VENDORS, INDUSTRY SPECIFIC EXPERTISE

- One potential near future development may be specialist 2D vendors for particular customer applications and industries

"We're closely tied with two vendors. We're still trying to fully vet their experience. The two applications we're working on at the moment, it's a matter of the expertise with one versus the other. We've got some that are better suited for low bay non-rack supported type buildings. They've got a lot of them in the US. And then we've got another solution, that's a 100 foot plus rack supported building and the experience with those high-bay type applications is really important." [DCS]

"On pallet shuttles we're open to working with different suppliers depending on the project requirement. We can often get into conversations with many companies who make pallet shuttles." [Korber Supply Chain]

FINAL CUSTOMER PARTNERSHIP INFLUENCE

- Possibly the most important aspect is the end-customer preference, if they have one

"At the end of the day sometimes you will have a client that wants something from Europe because they think the service will be quicker and things like that. The money will stay in the Europe, even better, or things like that. But sometimes you've got a client who will say, 'I got budget like this and can I go any further, can we have something which will be working?'" [MGL]

- Such preferences may not be overt, but may be an important factor to consider for partnerships

"With regards to selecting the right 2D pallet shuttle vendor. It's really understanding customer's requirements. We need to understand what the customer is looking for and if they've got any constraints. I recently had one customer say they only want European technology. Other customers will say they just want the cheapest thing in the market, and a European supplier may not hit that nail right on. Then you need to assess who is able to provide a 'cheap' system, but also reliable? Because we're going to be putting our name to it. We obviously don't want to have a cheap system that is unreliable. We want a system that's reliable and cost effective." [Korber Supply Chain]

END-CUSTOMER PREFERENCES ALSO INFLUENCE THE CHOICE OF 2D SHUTTLE VENDOR

Types of End-customers



'Reliability Realist'

- Have preference for low risk, multiple reference sites, easy service & maintenance, etc.



'Bottom-Liner'

- Have preference for lowest cost



'Homegrown Champion'

- Have preference for domestically produced products and willing to take a price premium

Source: STIQ Ltd Research & Analysis

- This may also extend to less advanced components, such as the racking

"Using racking suppliers from overseas depends on the customer industry. If you're talking defence, they don't meet the criteria so the other applications I would say." [Burns & McDonnell]

INTERVIEW: THE SYSTEM INTEGRATOR CURRENTLY EVALUATING PALLET SHUTTLE SEEING PARALLEL DEVELOPMENTS FROM CASE/EACH ASRS REPEATING IN THE PALLET ASRS SPACE

Pallet Automation 2026
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CURRENTLY EVALUATING MARKET & VENDORS

- STIQ Ltd interviewed a System Integrator currently in the process of evaluating the global 2D pallet shuttle market for potential partners

"I work in portfolio management and right now I am screening the manufacturer's landscape for 2D pallet shuttles. I'm trying to gain centralized knowledge about pallet shuttles and transfer as much knowledge as possible through our organization. A big part of this, right now, is screening the manufacturer's landscape and that's why it's fitting to have a chat with STIQ and to talk about exactly this in this meeting." [Anonymous System Integrator]

2D SHUTTLES ON TREND NOW

- 2D pallet shuttles are definitely on trend and the company wants to officially partner with a vendor or two

"The reason we're doing this evaluation now is we are seeing rising demand of 2D pallet shuttles. We've been seeing a lot of specific requests from customers especially from North America... we are also building a pallet shuttle system there right now. Also, if you attend any trade fair at the moment, you'll see a lot of these devices." [Anonymous System Integrator]

PALLET & TOTE ASRS DEVELOPMENT MIRRORED

- The warehouse automation sector have experienced a move from cranes to shuttles in case/ tote-based systems and some observers draw a parallel between these events

DEVELOPMENTS IN CASE/EACH ASRS APPEARS TO BE MIRRORED IN NEW PALLET ASRS TECH

Case/Each ASRS tech evolution →

Development from shuttle to more flexible & scalable systems such as cASRS, mASRS, PA-AMR, VRG,

Pallet ASRS tech evolution ⇢

Early-stage evolution from legacy tech to more flexible systems, such as 2D Pallet Shuttle

Source: STIQ Ltd Research & Analysis

"We also offer cranes and what we have seen in the market is the transition in tote based ASRS from cranes to shuttles. And, this is now taking place for palletized goods." [Anonymous System Integrator]

MARKET MOVE FROM LIGHT LOAD TO PALLETS

- Plenty of customers have focused on automating lighter goods storage & retrieval with the market now appearing to pivoting to pallet and heavier goods storage

"A lot of customers have focused on lightweight solutions, case handling, and have automatic warehouses with shuttles, conveyor lines or whatever. So, they have covered lightweight storage. Often, they manage pallets manually and are now starting with automating this area, pallets or heavy weights." [Anonymous System Integrator]

PROVIDING A SOLUTION, KEY TO SI

- The focus for this SI is to provide higher value integrated solutions rather than a standalone single system which could potentially be sold directly by a vendor

"A pallet shuttle systems for us just makes sense as a part of our solution offering. We will never sell just a pallet shuttle system as a standalone system because this is not what we're good at." [Anonymous System Integrator]

- All SIs have partners and there is a level of rationalization to ensure the focus for the SI is on higher value work, for example including the racking in a 2D shuttle vendor partnership

"We do have some partners, but I think it's more about having to deal with multiple parties and realization in the implementation of a project. Preferably we would have one partner for pallet shuttles and a single point of contact. It's not only about a single point of contact, it's also about these parties being aligned with each other. If a pallet shuttle manufacturer offers everything, we would assume they are aligned technologically and specifications are aligned between them. Then there are less discussions, less uncertainty in the sales phase and less friction during implementation. We've already experienced this in a pallet shuttle project. I would say it's also about minimizing friction and discussions about things that are fixed and defined with partners." [Anonymous System Integrator]

INTERVIEW: AN IDEAL 2D SHUTTLE PARTNER WOULD SUPPLY A TURNKEY SYSTEM (SHUTTLE + RACKING) BUT BEST OF BREED PREFERENCE MAY APPLY

YOU'RE ONLY AS GOOD AS YOUR PARTNER/S

- The ideal partner has an advanced technological level with an ability to supply a turnkey solution, not only parts

"We are an integrator, so we have not only the mechanical part, but also the IT scope. One of the biggest problems we are currently facing when we're looking for reliable suppliers or partners is that we would like not only to have a partner for the mechanical part, but also for the IT scope. So we're looking for a kind of black box system... for a strong technology partner with a comparable level to our quality expectation. Because in the end it's us who face the customer. If we have a supplier which can only provide the mechanical part, it wouldn't make sense for us to go further because we also need the IT scope. This would be one of the first gates, the delivery scope. Next would be the racking. Because it would make our life easier if the shuttle supplier can also sort out the racking in this scope of supply, a turnkey black box solution." [Anonymous System Integrator]

THE IDEAL PARTNER IS TURNKEY

- However, depending on the market and vendors, there may be trade-offs made for a higher technological solution without racking

"Partnering is always a kind of trade-off. We could accept to go for a vendor without the rack. But our preference is for a vendor who's also supplying the rack. The IT scope is not in question, but racking can be discussed." [Anonymous System Integrator]

- Part of the racking issue is the relatively high proportion of the rack cost as part of a typical 2D shuttle project

"Also sometimes racking contains like 60-70% of the total project. For example, if we look at a project with 5-10,000 pallet locations, you have perhaps 10-12 shuttles and the price for these is not comparable to racking part." [Anonymous System Integrator]

NO SPECIFIC GEOGRAPHICAL PREFERENCE

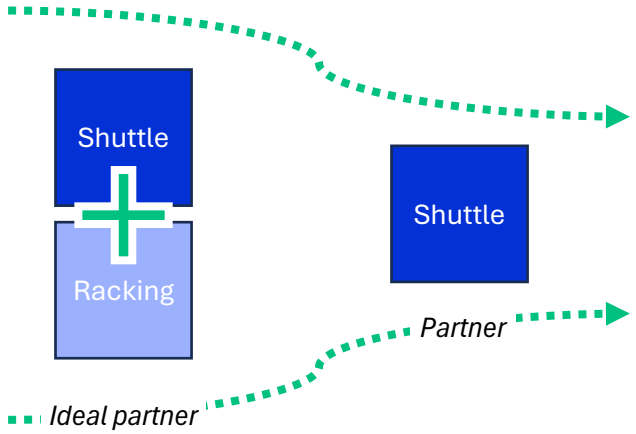
- There is no geographical selection preference, but having a local product may be easier for a local project, etc. and Asian vendors have fewer references in Europe, etc.

"We are not consciously preferring Asian, European or North American manufacturers... The technology is more or less commoditized and there are no big hardware selling points. Of course, using a European vendor may put you in a more favorable position for a European project just because the whole infrastructure is already there. Similarly for a North American vendor. There are not a lot of Asian vendors with real references in Europe and that's holding them back or putting them lower on the list, just because they don't have many installations or references. But they are still in consideration, of course." [Anonymous System Integrator]

- However, there is a perceived preference for local vendors among some customers

"We're also observing some end customers wanting a local manufacturer in principle, just because they've had good experiences with them, and they trust them more. It's also kind of risk management for customers." [Anonymous System Integrator]

2D SHUTTLE PARTNER EVALUATION FUNNEL: THE IDEAL PARTNER A TURNKEY SUPPLIER



Source: STIQ Ltd Research & Analysis

- In the end, there is a variety of customer preferences from local vendors to the most cost effective and more

"Some big end customers just prefer European manufacturers or maybe a bigger brand because they put a big emphasis on those kind of things. But at the same time, there will be a lot of customers that just don't care and do not have this pre-selection process. Other end customers treat their supply chain or intralogistics as a cost center and then they don't put as big emphasis on the partner selection or the manufacturer selection." [Anonymous System Integrator]

INTERVIEW: SOFTWARE FUNCTIONALITY IS VERY IMPORTANT IN 2D SYSTEMS WITH ROAMING FLEET OF SHUTTLES AND AN INTEGRAL PART OF THE DUE DILIGENCE PROCESS

SOFTWARE PARAMOUNT FOR 2D SHUTTLE

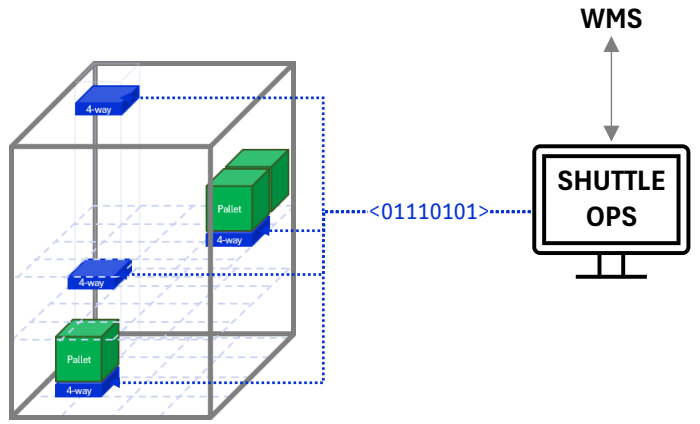
- The software is far more important in a 2D shuttle compared to captive or single aisle shuttles as there is more complexity with managing a fleet of roaming shuttles

"Software is a very important part when it comes to these roaming 2D shuttles. Captive shuttles which move straight in a single aisle is a kind of easy on the software side. But for roaming or 2D pallet shuttles... we are always talking about horizontal roaming pallet shuttles... the software includes all the strategies for storage and retrieval. This is something we need to buy from our partner because they are the experts. We have expertise in our own systems, but for now, not for roaming pallet shuttles." [Anonymous System Integrator]

- Part of the evaluation process is to run multiple simulation scenarios, such as LIFO, FIFO, sequencing, etc.

"When we talk to potential partners, undergoing the evaluation phase, we need to have a good feeling that the partner really is able to do what they tell us. From a software perspective, this has to be proven by simulations, not a simple Excel calculation. For example, if we have FIFO strategy, how does your system operate? Can you prove that your system is well designed? What if there is a fault in the system, what happens? Usually, we require a simulation from a partner, typically as a part of a workshop. There we discuss about these strategies. If we are confident that this is the right partner, the right system, then we will move on and go into real projects." [Anonymous System Integrator]

2D SHUTTLE SOFTWARE IS PARAMOUNT, MANAGING FLEET OF ROAMING SHUTTLES, ETC.



Source: STIQ Ltd Research & Analysis

CUSTOMER DUE DILIGENCE, MISGUIDED?

- There have been instances where customers avoided PE backed suppliers due to perceived risks (may include potential future ownership, etc.), but this disregards the ownership structure that can be opaque for many vendors

"In a North American project there was a big end customer, that refused to work with a PE backed vendor. The reason was some of the associated risks and this customer did not like that. So here it was the end customer that excluded some vendors because of a perceived potential risk. But, if you look some Asian companies, it's really, really hard to even find out about the backing of those companies. For us as a partner, as a system integrator, it doesn't make a lot of sense to put a Western PE-backed company on a blacklist simply because of their backers and at the same time evaluate Chinese manufacturers. This is of course part of our partnership risk assessment... the company structure and also how we expect them to behave in the future. Let's take, for example, a vendor and if they're sold to a system integrator in five years. Then we will have the buyer as our source and we could potentially run into problems." [Anonymous System Integrator]

INTERVIEW: CUSTOMERS ARE INCREASINGLY DISPLAYING A PREFERENCE FOR NEW TECHNOLOGY, SUCH AS 2D SHUTTLES

CRANES PERCEIVED AS LEGACY TECHNOLOGY

- The primary alternative technology is cranes which can be perceived as outdated technology by some customers

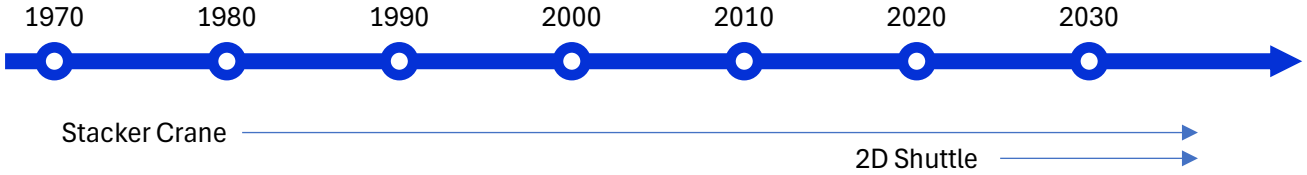
"There are customers who think cranes are old fashioned technology and would like to have the latest technology, such as 2D shuttles. They want to be more flexible, more reliable and move away from this single point of failure which very often is mentioned as a customer concern." [Anonymous System Integrator]

- However, cranes are tried and tested and prices are reasonable, but these solutions do not fit in all circumstances, especially as the market may be moving towards more brownfield opportunities

"But when we go into deeper discussion, then we're also talking about the cost of a 2D system. Customers seem to say, okay, shuttles are more expensive than cranes and maybe we have to think again. But when we're looking at existing real estate this is mostly brownfields and the footprint is rarely ideal for crane aisles. Here a pallet shuttle could be a more suitable solution... for irregular shapes in building, etc. This is also a reason why we are considering expanding our portfolio in this direction." [Anonymous System Integrator]

- While cranes can be a cheaper and tested option, not offering a new technology such as 2D shuttle, may also exclude an integrator without the tech from a project discussion

STACKER CRANES VIEWED AS LEGACY TECH COMPARED TO MORE MODERN 2D SHUTTLES



Source: STIQ Ltd Research & Analysis. Approximate time scale for when technology emerged

LEGACY CRANES EOL, RIP & REPLACE?

- There is a large install base of pallet stacker cranes and some of these systems are now coming to their end of life where the option can be replacing with a shuttle technology

"A lot of stacker cranes have been installed in the last 20-30 years and some of those are at the end of their lifetime. Some clients are contemplating whether to continue with maintenance or replacing. One option is to rip & replace with new technology like a pallet shuttle." [Anonymous System Integrator]

STACKER CRANE COST ADVANTAGE

- Cranes are legacy technology and remains a low-cost solution, but some customers prefer new technologies and it is always good to have adjacent technologies that can be applied in solutions

"Stacker cranes are not the newest technology, but they are cheaper per storage location... or more economic in a lot of applications. It's often a matter of the use case if a pallet shuttle fits better, especially in brownfield projects. A lot of end customers have a preference for new technology and want to apply the state-of-the-art technology into their project. There's a lot of factors coming together and we treat it as an addition to our portfolio because we do see the demand is increasing. And of course, if there is a technology that can be applied to our other solutions, it's always a good addition to have." [Anonymous System Integrator]

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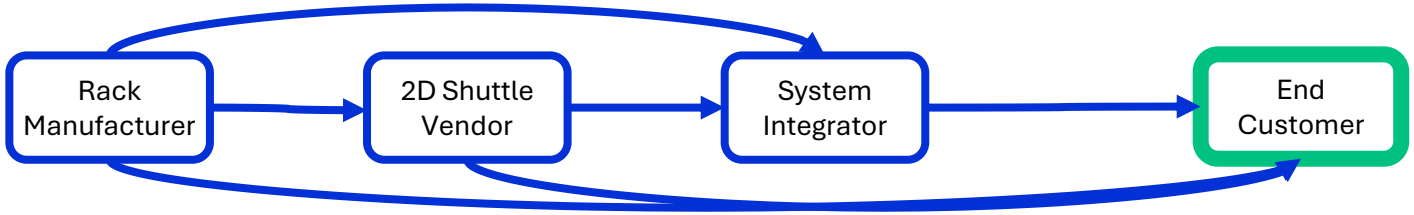
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A NASCENT MARKET OFTEN FORCES OEMs TO GO DIRECT TO CUSTOMERS. AS A MARKET MATURES, SYSTEM INTEGRATORS BECOME MORE AND MORE INTERESTED

CURRENT GTM STRATEGIES VARY DEPENDING ON PROJECT COMPLEXITY, CUSTOMER REQUIREMENT, VENDOR POLICY, COUNTRY, ETC. (SIMPLIFIED)



Source: STIQ Ltd Research & Analysis

2D SHUTTLE ROBOTICS AS A SERVICE

- A number of vendors have also spun up new business models offering RaaS type robot rentals where customers can ramp up/down throughput based on their sales forecasts and/or plans

"We offer short-term rentals for shuttles and we always encourage customers to under-dimension the system. If you say, I need 20 shuttles, I say start with 15 and let's see where we get. Which is something you can do. We have shuttles in stock. If you call me, you'll get it installed tomorrow. It's easier to install, to get the rental shuttle, etc. than to get a rental forklift. Because all shuttles are identical." [MOVU Robotics]

THE DIRECT ROUTE (DUE TO NECESSITY)

- System integrators tend to be risk averse and new system vendors often have to deal directly with end customers the first few years in order to create reference projects and also simply because there are no other options

"The first 10 years we dealt directly with end customers and now the integrators are coming in… what they said five years ago, is that it's too new and we don't know enough about it. Right now, we're also working a lot with several big integrators, but that's only really started happening in the last two years. Things have really started taking off over the past 2-3 years." [Logiqs]

GTM AND PROJECT COMPLEXITY

- As the market matures and projects grow in complexity, system integrators become a more important partner to bring together larger solutions

"Integrators build wholistic solutions around our sub-system. We try to be the very best inside our block itself, where so to say 99% of the scope is coming out of the stow Group supply chain." [MOVU Robotics]

SOME VENDORS FOCUS EXCLUSIVELY ON THE 2D PALLET SHUTTLE SYSTEM AND MAY OR MAY NOT OFFER RACKING. PLENTY OF DIFFERENT GTM ITERATIONS

MULTIPLE DIFFERENT GTM STRATEGIES

- Many 2D shuttle vendors go directly and via channel partners such as system integrators

"We have 3 types of business. Direct business, mostly in full automatic systems. We sell, develop, study and realize the full automatic systems by our own. And then we have dealer market. We sell directly and via dealers in US and in Italy, and only to dealers in RoW." [Automha]

- Others take a different approach depending on markets and channels

"In China we work directly with end customers and also with integrators. It depends on the customer's idea. In overseas, it is mainly through our channel partners. In China it's maybe 50/50." [Zikoo]

THE EXCLUSIVE 2D SHUTTLE VENDOR

- A small number of shuttle vendors work exclusively with system integrators or other channel partners

"We only do shuttles. We also do heavy–load shuttles, niche shuttles for crazy shapes, etc. Our focus is just the shuttle and to make all the applications that you can imagine. We do customized shuttles as well. We partner with system integrators exclusively... even in China, which is a very competitive market, low margins, etc. Sometimes it's easier to go around the integrator and work with end customers directly to get more margin. But even in China, we value our partners." [ZS Robotics]

"We're selling exclusively through system integrator partners. We feel that's important. It's hard for us to be an expert at everything. We really want to own our piece being the pallet shuttle, the controls driving that, the hardware associated with that and the software driving that all." [Aistorage]

- As racking is a major part of projects, some vendors may work with channel partners and may source racking for them as well

"A lot of value for a project sits in the steel and a lot of the companies look for partners to be able to supply the whole project as part of the partnership. We're quite agnostic in our approach to steel and if that means that the end user or in this case the system integrator can sort out the steel themselves and we supply all the shuttle hardware and part of the software." [Rainbow Dynamics]

OTHERS OFFER OPTIONAL FULL TURNKEY

- Other 2D shuttle vendors can act as turnkey suppliers or via system integrators

"Racking is a big part of 2D shuttle projects. Some vendors provide racking fixed with their own shuttle. Other vendors are a little bit more open. In the end, the racking still needs to be validated and approved by all parties." [Korber Supply Chain]

"We could do a full turnkey solution... including the racking, software, etc. or we can just do the automation part of it depending really what the customer wants." [Spacemaker Systems]

- This is also somewhat encouraged by rack vendors

"We work with OEMs and integrators where we work with for many, many years and have standard contracts in place. No worries, no risk. We also offer the opportunity to go on a three-way contract. So that yes, we are open for an end customer to buy direct with us." [NEDCON]

- Some vendors simply offer the 2D shuttle system including racking

"We provide the entire solution, not just the shuttle robots. The shuttle, racking, everything comes as a solution under us. Where we source racking depends on the country and if there are regulations." [Geek+]

- At the other end is the system integrator with their own racking supply

"We go directly to market as system integrators, offering a complete solution that includes racking, machinery, and software. Around 90% of our projects use products manufactured in-house." [Mecalux]

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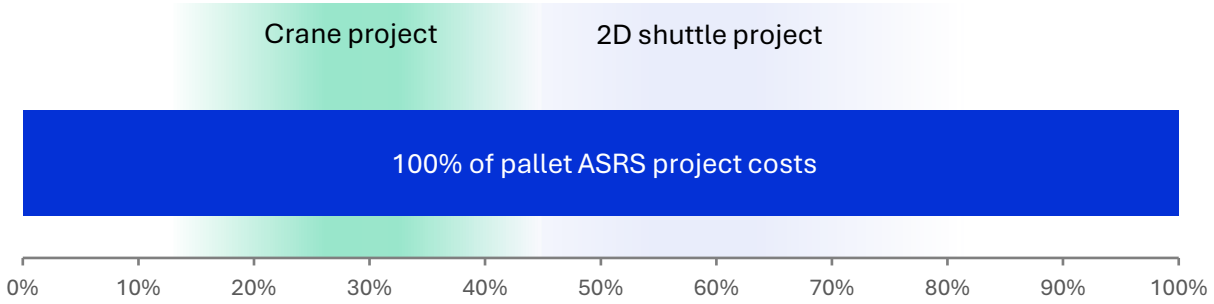
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RACKING COSTS REPRESENT A SIGNIFICANT PROPORTION OF 2D PALLET SHUTTLE PROJECTS. EXACT % CAN VARY DEPENDING ON COMPLEXITY OF DEPLOYMENT

PROPORTION OF RACKING IN STACKER CRANE VS 2D SHUTTLE PROJECTS



Source: STIQ Ltd Research & Analysis

RACKING AS A % OF 2D SHUTTLE PROJECTS

- Racking costs average between 50-70% of a typical 2D pallet shuttle project

"Racking is normally... it depends... but I would say it stays between 40-60% for 2D shuttles. Racking is still the pain point. Because we really cannot control that. That is related to cost of steel and all that... the good part of that is that no one controls it." [Anonymous]

"The costs for racking in a 2D pallet shuttle system are higher than in a classic high-bay warehouse... probably up to 60-70%. In high-bay warehousing it depends on the surrounding systems, on conveyors, on your overall design needs. There are systems with up to 50-60% racking of project costs, but other projects probably only 30%... it always depends." [Toyota Automated Logistics]

"The racking cost for a 2D pallet shuttle system is 60-70% racking." [NEDCON]

"The racking typically represents 60-70% of the total cost of a 2D pallet shuttle system." [Eurofork]

"The biggest share of the cost is the structure, and that's standard racking." [Mytra]

"Racking 50%. Shuttles 10%. 40% peripherals, solutioning, installation, conveyors, weighing systems, Wi-Fi infrastructure, installation, transport, software and elevators." [Anonymous]

% DEPENDS ON COMPLEXITY OF PROJECTS

- The real proportion of racking often varies depending on the complexity of projects, i.e. if the 2D pallet shuttle is only part of a larger solutions with mixed automation, etc.

"Let's say 50/50... deployment costs, software, a bit of conveyance. You need some controls, lifts, vertical conveyors and shuttles... 50% racking, 25% shuttles, 25% all the rest. But that's really average. The value of the robots themselves is often overstated because everyone is in love with the machine. But it's about the application and how you make a design, how you design the rack, how you do picking. It's much more than just a robot." [MOVU Robotics]

"Sometimes the pallet racking for 2D shuttle systems represents 50/50 or 40/60. It all depends on how big and how high the installation is, how many pallet positions and other things. For example, walkways, ladders, tensioning... it all depends on things like that." [MGL]

"We did big projects where the racking was 76% and the automation only 24%. We also completed smaller projects and just signed off a new customer last week where the racking was 33% and the automation 67%. But that was a smaller system. It really depends on the weight of the pallets and the size of the system." [Logiqs]

"Racking plays a huge role in the overall 2D shuttle price composition. That can account for up to 60-70% of the total cost. There's no way of looking at the total cost without looking at the rack. But it can vary. One customer have SKUs that don't move for years. It's very slow movement, a huge amount of storage... I suspect racking could be 90% of the cost and picking direct off pallet is paramount It's all about storage density." [Rainbow Dynamics]

2D PALLET SHUTTLE RACKING IS DIFFERENT TO STANDARD RACKS

2D SHUTTLE RACKING IS SPECIFIC

- 2D shuttle systems require special racking and finding the right combination of shuttle and racking suppliers can be key to a successful project

"For a 2D shuttle system you have to focus more on the right racking partner. For a stacker crane... any rack looks nearly the same, and you have the FEM rules and they work. There are a lot of racking suppliers who can handle such projects. When it comes to pallet shuttles, usually the pallet shuttle suppliers have their own type of profiles that they need for their shuttles. You have to focus on good quality of the racks so that the shuttle doesn't get stuck somewhere in the aisle. It's still a pretty new technology after all, even if it's some years in the market." [Toyota Automated Logistics]

- 2D shuttle racks are more complex

"For a crane you can buy racking from pretty much anyone. The only connecting element is the rail sitting on top. It has to conform with FEM norms. But if you buy from a reputable player, you don't need anything else than a good drawing and an offer. This doesn't work for 2D shuttles because the requirements of the rack are quite different. They're also vary from vendor to vendor. It depends a bit on the weight of your machine, on the position of the wheels, etc. We have to go through requirements in detail with a racking suppliers more than we would have with a crane." [Addverb]

- Racks may also include aluminium profiles

"We're seeing more and more 2D shuttle projects. But the one issue with 2D shuttles is there's a lot of transition between the rack and aisles and up and down movements. So a 2D shuttle consists of a lot more than just structural steel because a lot of those rails are aluminum profiles, light gauge profiles and those generally shuttle manufacturers have their own supply chain, mainly from Asia for these rails and stuff. And then they are looking for us now to quote those parts. But these are specialty roll form components. You need special roll forming equipment, which is very expensive investment wise." [Steelking]

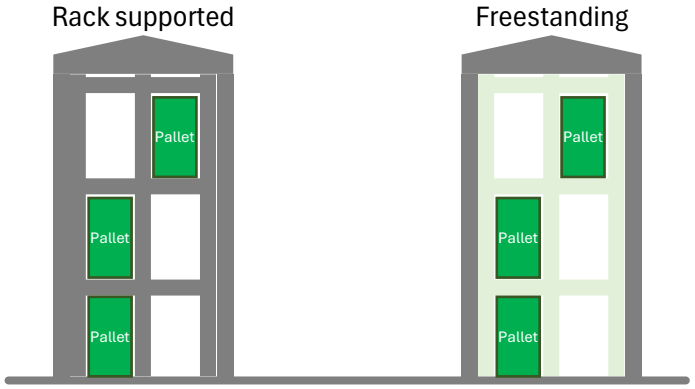
DIFFERENCES BETWEEN STANDARD PALLET RACK AND 2D PALLET SHUTTLE RACKS (SIMPLIFIED)

Standard Rack	2D Pallet Rack
• Static load bearing racks • Manual forklift driver can visually compensate for any tolerances • Damages mainly due to manual drivers	• Load bearing racks in same fixture as robots move with often heavy payloads on L-profiles • Very limited tolerance compensation by robots - including both manufacturing and installation tolerances • Weaknesses may appear over time by robot movements • Often integrates with vertical lifts

Source: STIQ Ltd Research & Analysis

RACKING TAKES ON MORE IMPORTANCE WHEN USED IN RACK SUPPORTED BUILDINGS VERSUS A FREESTANDING BUILDING. RECENT CHANGES TO US CODES

RACK SUPPORTED VS FREESTANDING WAREHOUSE BUILDINGS



Source: STIQ Ltd Research & Analysis

GREATER RISK IN RACK SUPPORTED SHEDS

- Risks may be more accentuated in rack supported buildings due to the added complexity

"There are some applications where we do the racking for rack-supported buildings, when the racking is part of the building and we're going to want to have a say in how that's designed, built and constructed. When we're talking about what we call box-in-a-box design, we don't care who's doing it. We would like to manage it ourself because of quality and all of that is what we're focused on. If you think about, who's got the crane on-site and who's got the access to the crane, it becomes sometimes easier for us to manage it all. We don't care as much as long as there's low risk in delivery." [Burns & McDonnell]

2024 CHANGES TO RACKING STANDARDS

- Recent changes to building US codes (IBC 2024 and mandatory DAM for buildings) may have had an impact on racking suppliers

"Everyone wants cheaper racks, which typically ends up being from Asia. But that's changing as suppliers come in and realize they have to engineer for US codes... and especially now there's been a big code change recently for how you engineer racking. The new method of engineering racks is called 'direct analysis' and it requires you to now consider the rack as a system versus a single upright and beams." [Steelking]

- Interviews suggest recent changes to building codes are a significant upgrade to previous testing methods

"This is one of the biggest change in rack engineering in the last 20-30 years. Rack manufacturers who are used to manufacturing, either buying rack from Asia or Europe, they may not be familiar with these standards. It's not rocket science, but still, you have to do some testing of beams and columns. And that's why I think many people are realizing it makes sense to work with someone who knows US code, and who has done testing here." [Steelking]

RACKING PROJECTS ARE OFTEN EXTENSIVE

- While hypothetical, a potential bottleneck for the 2D sector could become lack of racking capacity, either manufacturing or installing as projects can be very long

"That's one of the big challenges in our industry, and especially looking at ASRS providers, the cycle of our projects are regularly 12-18 month long project cycles and you're never going to get lucky and get those projects to overlap in the perfect arrangement where you can keep your resources fully utilized. We've found a lot of economy and savings there being able to use a bigger commissioning team when we need and pull from our sister groups when needed. When we have a lull where we aren't actively commissioning a project or project site, those people aren't on our payroll and adding to overheads. It's nice that we can kind of scale up as project work comes in, we have overlapping projects." [Aistorage]

"Project cycles for 2D shuttles are typically longer than you anticipate... revenue conversion can drag out." [MOVU Robotics]

"And while we get a lot of these projects... quite a substantial amount of these larger projects have a very long execution time." [NEDCON]

- Lead times are often long partly due to installation time, but also in the design phase

"With rack supported or general ASRS, there's a lot of back and forth coordination. Just the engineering can take over a month and for permitting and fabrication, it could be 2-3 months. That's why the life cycle of the project is long." [Steelking]

SINGLE SOURCING 2D SHUTTLES + RACKING HAS SOME ADVANTAGES CURRENTLY WHICH MAY DISSIPATE AS THE MARKET MATURES. MULTI SOURCING ALSO HAS ADVANTAGES

SINGLE SOURCING SHUTTLE + RACK

- ingle sourcing shuttles and racking from one vendor can have advantages, but is typically only one of many evaluation factors for system integrators

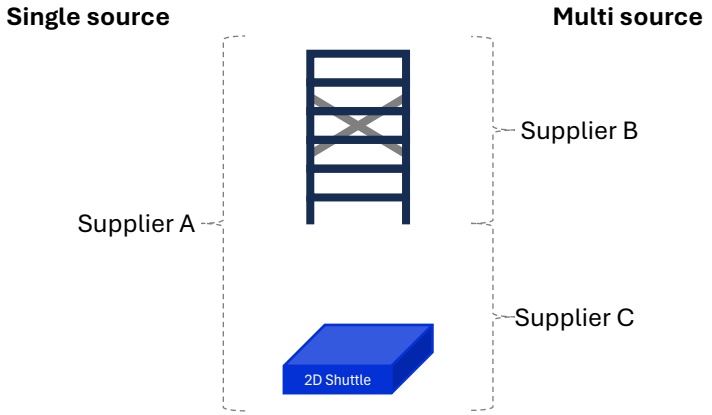
"The single source 2D shuttle + racking has played a factor in the selection. But it's lots of different things that come to that vendor benchmarking. It's not just a case of just because they supply everything that makes it easier. There's lots of different factors." [Korber Supply Chain]

"For the 2D shuttle specifically, we went with this vendor largely due to their expertise and the amount of live installations they have. If you think about the emerging 2D shuttle system vendors in the market, not a lot of them have live installations. This vendor is still the market leader. And the other thing I value is they're able to take on the rack and the shuttle. There's less concerns about is the rack I'm going to provide, are the rails going to fit perfectly into the shuttle, etc. That's one of the risks that, at least on the integrator side, we try to minimize. I'm always cautious providing rack for a robotic system. I always prefer that the robotic vendor is responsible for the rack they're interacting with, especially when it comes to these 2D shuttle systems." [Equipment Depot]

MULTIPLE RACKING SUPPLIERS CAN BE GOOD

- Having multiple racking suppliers can potentially be a good thing as they each may have specific local expertise

SHUTTLE + RACKING SINGLE OR MULTI SOURCING



Source: STIQ Ltd Research & Analysis

"There's obviously some challenges competing there sometimes if a vendor can provide the total solution including the racking. What we've found, more often than not, the thing on location in the country, seismic levels, how high we're going, what industry we're in, it's hard to find a single rack manufacturer that is the ideal partner for every one of those sites." [Aistorage]

- Many 2D pallet shuttle vendors have partnered with multiple racking suppliers to provide options for system integrators

"To date, we have homologated approximately 13 racking providers, giving integrators the flexibility to choose the most appropriate solution for each project while ensuring compatibility, performance, and adaptability to different market requirements. We recognize that there is often no single solution that fits every project, which is why we aim to ensure the most appropriate solution can be selected for each specific application." [Eurofork]

MULTIPLE RACKING SUPPLIERS MAY BE GOOD AS COST OF STEEL CAN BE AN INFLUENTIAL FACTOR. SOME RACK VENDORS TRYING TO DEVELOP STANDARD 2D SHUTTLE RACKS

RACKING AS A % OF CRANE PROJECTS

- Racking represents a far lower share of crane related projects when compared to the 2D shuttle

"For cranes, racking is between 20-30%. And, and the rest is all accessory costs and commissioning stuff." [Anonymous]

"About 35-40% of CapEx is racking in a crane project. The rest is the crane, automation and the conveyor loop and all that stuff. When it comes to shuttle systems, it's towards 50-55% for the racking itself. It is significant because the automation vendor is only bringing in about 35-40% and the actual hardware itself. If you talk about just the 2D shuttles, that's even less." [Acme]

THE COST OF STEEL INFLUENCING PROJECTS

- While interviews have suggested that steel price changes have a limited impact on 2D shuttle projects, it is likely this is tracked by customers

"The cost of steel has increased so much and that's bringing up massive value just in the racking. I think we need to get the cost of racking down a little . It's very high for this space because we need all the rails, aisles and walkways." [Moffett]

"Steel commodity prices can influence demand. But it's also that some racking suppliers are now investing more in 2D racking lines and that helps a bit to getting prices down. One of the European racking players I was talking to already for 2-3 years, and in the beginning they were 2X the cost of the others and now they're all on par... So there is actually a lot of development ongoing, you also see that more players are getting, from the racking side, interested in this piece of technology, because a lot of market is going there. Otherwise they miss out if they only do the stacker crane part. I think this development will help a bit in getting more cost competitiveness for the rest of this commodity of course, let's say, steel price, transportation cost, etc." [Addverb]

STANDARDIZED RACKING/ RACKING VENDORS

- Some racking vendors are trying to push 2D pallet vendors towards standard racks and measurements which could also help to drive down prices

"It's really strange that we should adapt our rack to a shuttle. I mean the big savings is, and we've seen that as well, with shuttle suppliers who are open to our suggestions and that we say, okay, can you change the position of the wheels? Or if you do that, then all of a sudden you gain 10-15% in your car's overall cost. These are very important things to discuss." [NEDCON]

DEVELOPMENT OF STANDARD RACKING FOR 2D PALLET SHUTTLES (ILLUSTRATIVE ONLY)



Image source: Gemini, STIQ prompt

BUT ANY SINGLE SOURCING ADVANTAGES MAY DISSIPATE AS THE MARKET MATURES AND INTEGRATORS EVALUATE EXPERIENCE RATHER THAN EASE OF SOURCING

SINGLE SOURCE, QUESTIONABLE ADVANTAGE?

- There is a perceived advantage of offering 2D shuttle and the steel/racking in a package, but some integrators may want to be in control of sourcing decisions

"It's an advantage when you have the steel. The only disadvantage is that racking is different to automation. We can focus on the machines and on the software, and that's challenging enough. We see integrators like to stay in control, and they want one supplier for the automation and another for the racking." [Logiqs]

- Some system integrators do not view single sourcing as a particular advantage and treat the two as separate parties focusing on the experience of parties working together instead

"I don't see being part of a rack manufacturer as particularly positive. The way I treat that is, essentially, it's two separate entities. I don't necessarily agree that it's an advantage to have that in-house. If you talk about the price aspect of it, they were not as cost competitive as others. That definitely didn't hold true for the examples that I've experienced. The relationship between a 2D shuttle vendor and the racking vendor would be the advantage. Not from a price perspective, but the fact that they've worked multiple projects together. You need the specs of the shuttle itself and how it moves. So the more familiar you are with that, it just causes less issues or potential for issues down the road." [DCS]

SINGLE SOURCING ADVANTAGE TO DISSIPATE?

- The relative popularity of single sourcing may be due to the relatively nascent stage of the 2D shuttle sector and may dissipate as the space matures

"I think the advantage of offering shuttle and racking will probably decrease over time. But at the moment, it could be a benefit in a project." [Toyota Automated Logistics]

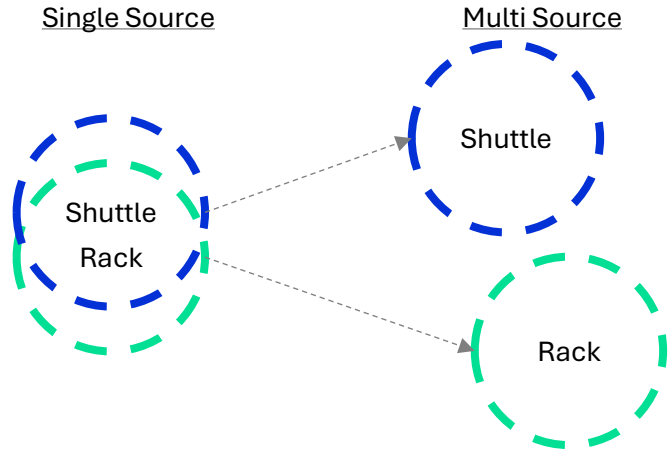
- Historical comparisons suggest there was similar behaviour when stacker cranes first appeared in the market

"In the past, I was always competing with crane vendors, some with their own racking. My sales guys were always saying these vendors had the advantage of their own rack and they don't have to put margin on it. I always said, they can only choose one partner and only have one price. In the case of 2D shuttles, it's similar. We see that the different suppliers come up with different pricing, sometimes also for different applications or geographies. I would not count on one supplier." [Addverb]

EXPERIENCE MAY BE MORE IMPORTANT

- The racking is paramount to the long-term success of 2D shuttles and experience of two parties working together may be more important than single or multi sourcing strategies

SHUTTLE & RACKING SOURCING STRATEGIES DEVELOPMENT OVER TIME (ILLUSTRATIVE)



Source: STIQ Ltd Research & Analysis

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WITH COMMODITIZING 2D SHUTTLE HARDWARE, SOFTWARE PLAYS AN INCREASINGLY IMPORTANT ROLE AS A UNIQUE SELLING POINT

SOFTWARE IS BECOMING KEY DIFFERENTIATOR

- The 2D shuttle form factor is similar among most vendors with some differences which means software is taking on a more important role, especially as these systems have a multiplicity of inherent potential functionality

"We're all the same in that we all lift ~1.5 ton, we all drive around ~1.5m/s. We all work in cold storage. After that, the business models are completely different. Some offer a machine with a traffic manager and that's it. At trade shows there are many suppliers offering the shuttle only. We're one of the only companies offering a turnkey solution, including all the software, traffic manager, storage manager, optimization, many different storage algorithms. Ultimately, it's the software that is massively different across these technologies." [Moffett]

2D SHUTTLE FLEET MANAGEMENT SOFTWARE

- There is a potential future where more system integrators take more responsibility for the 2D shuttle system software

"The 2D shuttle software itself, it makes sense to go with us rather than doing your own 2D shuttle software, because if you're going to just buy the hardware from us and do the software by yourself... It will come, but at the moment, I don't think many companies have the capability to run that kind of algorithm and that kind of software control by themselves. They could run the WMS layer, but when it comes to actually controlling the grid, it would be ideal that they get us to do that." [Acme]

- Many 2D vendors take the white-grey-black approach where they offer integrators to take deeper responsibilities but few may be willing to do this at this stage of the market

"In Europe you do see white-box software integration from time to time... I have one integrator who will work with us on a white basis where they control the hardware directly with their software. I think that's a very smart way of working, because it's more agnostic. You are less dependent on suppliers... if you have the capability to do this, then I would say go for it. In this case with this integrator, we also support this. But I would say 99% of the integrators in Europe go for the WCS, the grey layer. This could also be because many of the integrators don't yet have experience with 2D shuttles. They might have experience with cranes. Maybe they can do that with their software, but shuttles are still a different beast." [ZS Robotics]

- Some integrators may also want to focus on their core services rather than digging into each of the systems they work with

"We don't want to try to figure out how to optimize a 2D shuttle, that's not our expertise. We want the vendor partner to manage that. How to group orders and bring product out would be in our wheelhouse. We would just tell the system, hey, we need this pallet or this SKU... first, second, or how we sequence pulling product out. But in terms of how it's being stored, and where it's being selected, we let the shuttle system provide all that information and handle that." [DCS]

VENDOR WHITE-GREY-BLACK BOX OPTIONS FOR SYSTEM INTEGRATORS

WHITE	GREY	BLACK
• SI takes responsibility for entire system incl. 2D shuttle robot control system level	• SI takes over some light functionality like interfacing with other systems, internal WCS, etc.	• SI buys a complete 2D shuttle with software and only connects to WMS

Image source: Gemini, STIQ prompt

HARDWARE STILL PLAYS AN IMPORTANT ROLE

- While software will become an increasingly important unique sales point, software is nothing without the reliability of hardware

"When a machine stops operating at a height of 30 metres, even the most advanced software or artificial intelligence cannot by itself move a 1.5 Tons load. This is why hardware reliability remains a fundamental element of the overall system." [Eurofork]

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PALLET STORAGE AUTOMATION SIMPLY REQUIRES HIGH-QUALITY STANDARD PALLETS TO OPERATE AT SLAs AND IS FREQUENTLY UNDERESTIMATED BY POTENTIAL CUSTOMERS

ALL PALLET ASRS SYSTEMS REQUIRES HIGH-QUALITY PALLETS



Image source: Gemini, STIQ prompt

PALLET QUALITY AND AUTOMATION

- The pallet is a key part of a pallet ASRS system and if it fails it will directly affect uptime of the system

"In general, it's good to talk about the pallet. Because when you do projects, especially with shuttles, there are three important things. The first one is racking. The second one is the pallet. If you do something wrong with one or two, then you're done. I mean, there's no way the project can go smooth. And the third is clearly the shuttle itself that needs to be very reliable." [Swisslog]

- 2D systems are slightly more sensitive to inferior pallet quality compared to stacker cranes as cranes mainly use forks to pick up pallets

"And then there's the question also of pallet variety and how much the customer is willing to take control of the pallets they're putting in the system. Because when it comes to a shuttle system, it's an automated system, and automation loves standardization. When you try to feed a shuttle system a varying types of pallets, you'll see more failures, whereas a crane system is more likely to handle the varying pallets a little bit better with more tolerances than a shuttle system." [Equipment Depot]

ANY PALLET AS LONG AS ITS GOOD QUALITY

- While pallet quality is an issue, 2D systems can accommodate a degree of pallet variability

"Pallet quality is a critical factor for us to ensure that the system will deliver the performance that's required. We're adaptable in terms of pallets. We'll use the standard industry size pallet, EUR, CHEP, etc. If somebody comes to us with a special pallet, we've got the ability to redesign our technology to suit that application. The one thing we can't unfortunately manage is poor quality pallets. That just causes too much problems." [Spacemaker Systems]

"Pallet dimension variability can be an issue but if you can provide dimensions with a certain amount of variance, within reason, you can design the rails of your storage and there's a little bit of flexibility. But if you've got drastic variances, it'll probably get too rigid. You can still do it and have certain lanes be dedicated to specific pallet types. But I think that would not be a great application because you're just boxing yourself in and not really allowing yourself any flexibility for the future." [DCS]

QUESTIONABLE PALLET QUALITY

- Interviews suggest customers frequently underestimate the importance of pallet quality and some may hesitate at the costs of upgrading pallet inventory to a higher quality

"Pallet quality is questionable in about 50% of potential projects. A lot of end customers use the wooden pallet which are easily broken or deformed. In the Chinese market, customers accept to replace wooden pallets with plastic or steel pallets. Foreign customers can be a bit more cautious because for a big warehouses this can be a large investment." [Deliecn]

PALLET QUALITY DISCUSSIONS WITH POTENTIAL CUSTOMERS CAN BE SENSITIVE BUT ARE NECESSARY FOR PROPER ASRS FUNCTIONALITY AND OPERATION

CUSTOMER PUSHBACK ON PALLET QUALITY

- Conversations with potential customers can be sensitive as an inferior pallet quality typically means there is an additional investment in a higher quality pallet inventory

"Some customers do push back on pallet quality . But when you explain why , they tend to be a little bit more open to it. Because it's an integral part of a good working system. The pallet quality is always a thing." [Korber Supply Chain]

- One of the biggest challenges can be to communicate the actual importance of pallet quality

"Pallet quality's a big challenge. We see lots of variations... the biggest challenge is end-customers not understanding why the standard of pallets needs to be at a certain level to allow for automation. That's a major challenge. We've had a customer recently who wanted to put a certain size and quality of pallet into automation that just wasn't fit and that ended up with quite a long discussion with them around... their view was that it was the problem with the automation, and it took quite a while for them to realize actually it was the pallet quality that meant it didn't matter whether it was our technology or somebody else's technology. That standard of pallet just wasn't going to work with automation. That understanding from a client perspective is really critical." [Spacemaker Systems]

- Some customers delay or circumvent the importance of pallet quality which typically result in degraded system throughput with negative consequences for the customer-supplier relationship

"Even if we have everything signed, there is a proper information on the offer, etc., some customers don't understand it or try to solve the problems... try to make us solve their problems with pallets, basically." [Anonymous]

- A pallet ASRS mirrors AI software and using bad data input simply results in a bad output

"Bad pallets mean a bad system; it's very simple. We're honest with our customers about that. Some appreciate it, while others don't initially understand why we're raising a negative issue in the meeting." [Moffett]

- Some vendors would rather walk away from a project rather than ending up with the certainty of a problem project sucking up resources and unhappy customers

"In the US they are used to crappy pallets. I would say pallet quality is probably a bit better in Europe. But, if you look you see companies everywhere using very bad pallets. The point is customers need to understand this. If they don't understand that, then you don't sell to them. Otherwise you're just going to have issues with the system." [Anonymous]

"Customers who want to have ASRS, they start to calculate the cost of changing the pallets into better quality pallets, which is a huge investment. But pallet quality is the main problem that we face on a daily basis." [WDX]

LIVING THE PROBLEM, A WAY FORWARD?

- It can be difficult to appreciate the problem of pallet quality in automation unless you have experienced it, but this may be too late

PALLET QUALITY CAN BE A SENSITIVE ISSUE: MOVING FROM STATIC RACKS TO ASRS



Image source: Gemini, STIQ prompt

"I think our customers see the value in pallet standardization. But it almost takes them living with it a little bit to understand why that might be an issue. It's interesting because when they were working with static racks, they might not have seen it as an issue. You might visually look at the pallet and think, oh, that, that looks fine. But then when it fails getting through the shuttle system and you actually inspect it, it's like, oh, it is missing a bottom board." [Equipment Depot]

THE MOST COMMON PALLET ASRS SYSTEM FAILURE CAUSE IS RELATED TO PALLET QUALITY

WOOD PALLET AND DEBRIS ISSUES

- Wood pallets typically have some level of debris which can cause issues for automation

"Wooden pallets have a lot of debris. In the pharmacy sector, for instance, a lot has to be done on plastic pallets. If you work in aerospace or semiconductors, then plastic pallets are even more important." [Matco]

- The single most quoted pallet ASRS system failure cause is related to pallet quality

"I wish customers had a standard pallet. The commonality is we hear a lot of these customers have grade A GMA pallets. In the US, standard size Grade A is 40x48, and five bottom boards and all this criteria, and it's supposed to be the highest level pallet. But what we actually see on site is a different story. We've had a good amount of failures. I would say the highest number of failures on the system is due to pallet quality. There have been talks, and most of our customers are in agreement that they would like to standardize their pallets. And these systems are new, so they're still learning to live with them. But I see a high value in a standardized pallet and I think wooden pallets are more challenging to standardize, and maybe plastic pallets are the way to go with these shuttle systems. Because wooden pallets can be arbitrary." [Anonymous]

QUESTIONABLE PALLET WRAPPING QUALITY

- Pallet quality issues may also extend to the quality of wrapping especially in more advanced automation environments

SOME WOOD PALLETS CAN CAUSE ISSUES WITH CHIPPINGS ENTERING MACHINERY

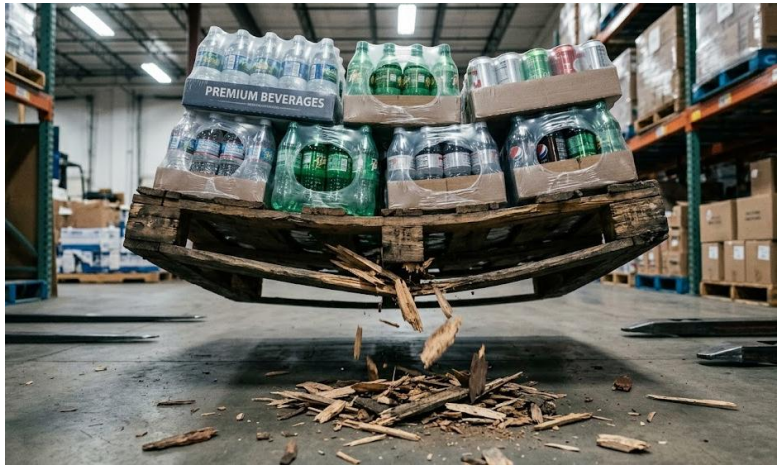


Image source: Gemini, STIQ prompt

"We also see where a pallet goes into an ASRS that it's quite important to have a very good quality of wrapping. You can imagine if you have film tails on the pallets, they will cover sensors which should not be covered. And then if you need to climb into a 30m high pallet warehouse to fix that and it's completely dark that's a lot of downtime. On the wrapping quality we see that there are more demands, especially when the automation grade goes higher." [Matco]

ALTERNATIVE OPTION

- Each customer may have different circumstances where the mother pallet may be more or less suitable

"Most customers know they need to have a standardized pallet. Sometimes customers use single-use pallets, and then they need to have a deeper look at the single-use pallets in order to make them work also in an automated warehouse." [Toyota Automated Logistics]

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3PL EVALUATION OF THE 2D PALLET SHUTTLE - A LARGER SOLUTION WHERE THE 2D PALLET SHUTTLE IS A COMPONENT IS MORE LIKELY TO PRODUCE FAVORABLE ROI

THE 3PL EVALUATION OF 2D SHUTTLES

- 2D shuttles are popular but relatively nascent technology

"That's how we started a discussion internally - we just said, Is the 2D shuttle the new Big Mac like a cASRS is for tote-to-person systems? The answer, for now, for us, is no." [Anonymous 3PL]

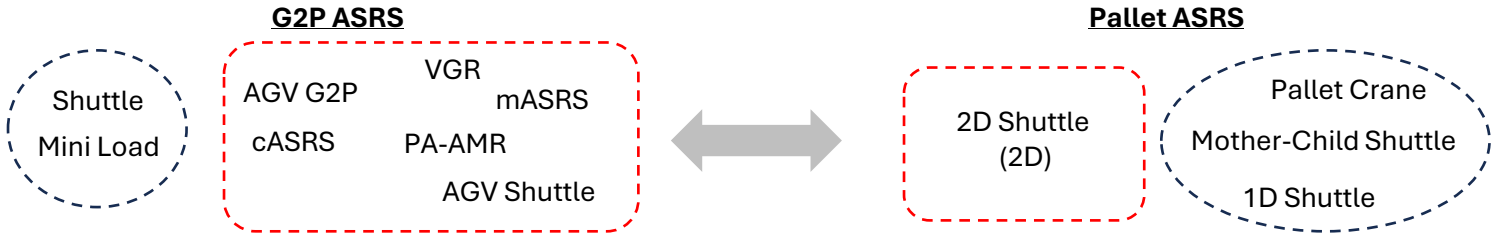
- The 2D shuttle technology looked very promising on the surface, but has proven more challenging on many levels than the initial concept suggested

"The initial promise of the 2D shuttle technology was that you can go into a normal building and just install the technology like you would install a cASRS, and then you have an automated pallet handling. That was the hope. But what we see in practice is that it's much harder to achieve the business case." [Anonymous 3PL]

- While the 2D shuttle is more flexible compared to other pallet ASRSs, there is far less choice in terms of technological differences between solutions, especially when compared to G2P Solutions (STIQs G2P reports)

"The 2D shuttle system is kind of flexible compared to any other pallet automation ASRS. But business cases are not as easy to achieve compared to manual handling in this space. But there are not so many options in this despite having a lot of suppliers. There are not many different options like in the robotic tote-to-person, cASRS, mASRS, shuttles, climbing systems, whatever. In this pallet space, there's not so much choice. We have been investigating this quite a lot since we have a lot of customer in the FMCG space and we already have a lot of crane systems and traditional pallet systems." [Anonymous 3PL]

EVALUATION OF 2D PALLET SHUTTLE: FEW DIFFERENT TECHNOLOGIES WHEN COMPARED TO G2P ASRS SOLUTIONS WHERE THERE ARE MANY DIFFERENT TECHNOLOGIES



Source: STIQ Ltd Research & Analysis

THE GREENFIELD OPTION

- The 2D shuttle can also be considered for greenfield opportunities, but all kinds of factors need to be considered to evaluate when and where there is a positive ROI

"We also think about 2D shuttles for greenfield opportunities. The problem is you with the traditional 12m clear height warehouse and normal building costs, it's hard to justify the business case. I mean, the handling you take away from pallet in/ pallet out helps a bit, but it's not a huge saving. The space savings are bigger, but only if the space costs are really high. If you can't go higher than 12m, it's hard to justify. It's the combination of these factors that will make it a viable business case. And, at the moment, that's not always given." [Anonymous 3PL]

SOLUTION THINKING CAN IMPROVE THE ROI

- Including a 2D pallet system as part of a multi-functional MHE solution would improve the ROI

"Of course, we are not looking at 2D shuttles for only pallet in/out typically. If we can have a full solution including, for example, layer or case picking, and so on then there are some advantages to improve the ROI versus just pallet in/out. You can have, you always have an automated replenishment, and if you just have case picking from an aisle inside or below the shuttle, then it's fully automated replenishment. You can just do a convenient picking route through this space... and this is still better than in the manual area where you need to do a top-down replenishment, for example. So this will always have business cases where when you have more than just full pallets in and out handling. I'm not talking about deep freeze or whatever special environments here. There are always different metrics playing a role." [Anonymous 3PL]

THE 2D SHUTTLE VERY SUITABLE FOR TEMPERATURE CONTROLLED ENVIRONMENTS AND WHERE THERE ARE A HIGH NUMBER OF PALLET MOVES

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FROZEN/ COLD IS A NO-BRAINER

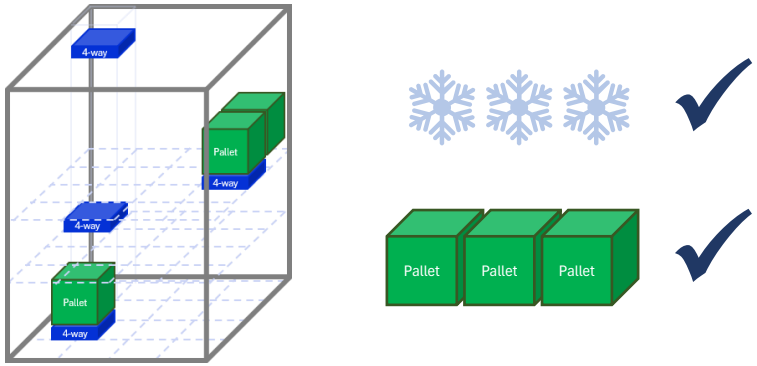
- The 2D pallet is a perfect solution for temperature-controlled environments where manual costs and operational limitations are significant

"For deep freeze or cold temperatures, storage density is king and the 2D shuttle is a great option. People can only work there for a few hours and then you need to change them and so on. It's very expensive to have people there. In special environments, there are easier business cases for 2D shuttles." [Anonymous 3PL]

- Density is critical for the 2D pallet and while temperature-controlled areas are a good fit, there are other cases where storing a lot of the same product can be suitable as well, but it often depends on the layout

"In the special case of temperature-controlled areas where you need density, 2D shuttles are always a good business case. In general, density matters a lot with this technology, so if you have the same product at lot of time, it will be very positive. And that's typically in FMCG, not in so many other spaces where you can get this. So this will limit the customers already. I think if it's just one deep, then its probably not competitive." [Anonymous 3PL]

2D SHUTTLE, GREAT FOR FROZEN + HIGH PALLET MOVE ENVIRONMENTS



Source: STIQ Ltd Research & Analysis

HIGH PALLET MOVERS

- The 2D system may be very interesting in a higher throughput system

"High movements of pallets is interesting. Really fast movers. If we make designs, we would put the fast movers into a 2D system and the slow movers outside the system, because the locations are too expensive for slow movers. Or we would do a combination of the fast and slow mover in one operation." [Anonymous 3PL]

- The higher you can go with a 2D pallet shuttle, the more economic and interesting the ROI case may be, especially in more standard warehouses

"The higher the better. I've seen some buildings now going to 15m and that makes it a lot more attractive, because it's not far away from the economics. In that case, with 15m, it becomes a lot more interesting, and that's still in a standard building. There are discussions... I'm not sure how, whether it's now completely done or not, but the new FM Global ESFR sprinklering is also good enough for 15m clear height, not just for 12m. It's something that also not all landlords are convinced of at the moment. This would help enormously for such business cases." [Anonymous 3PL]

STEEL/ RACKING REPRESENTS A SIGNIFICANT PROPORTION OF 2D SHUTTLE PROJECTS. SYSTEM INTEGRATORS MARGIN ON RACKING IS VIEWED AS NON-ADDED VALUE

LESS STEEL COULD BE GAME CHANGER

- Racking represents a significant proportion of 2D pallet shuttle projects

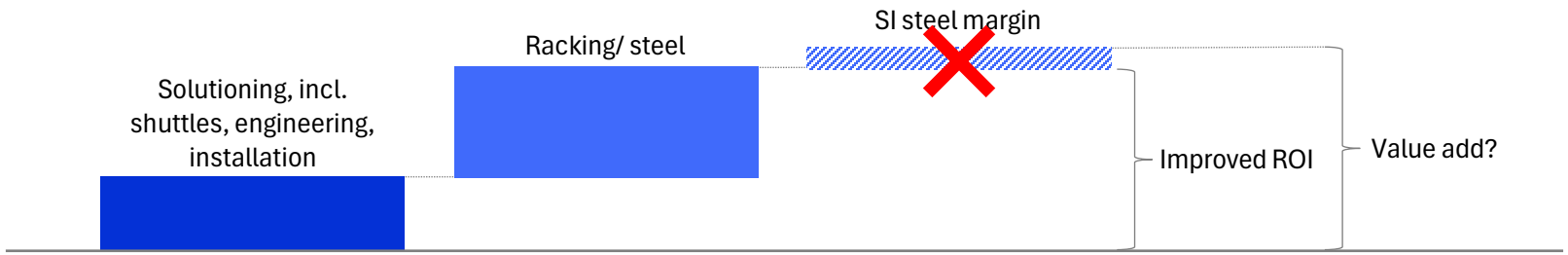
"To become more palatable, of course it needs to be cheaper, as always. The cost for a pallet position in a 2D shuttle system is six times higher than a normal pallet position... the CapEx... depending on how you look at it. Because you need a lot more steel. And this will make the initial investment very high for a decently sized warehouse. It's easily $10m which makes it difficult. I've seen different approaches by vendors to reduce the cost per location. When they find a solution that can use less steel, with lower cost per location, this will be a game changer in this space. Steel is a big part of these systems." [Anonymous 3PL]

SIs TYPICALLY ADD MARGIN ON THE STEEL

- Part of the cost conundrum for the 2D shuttle is system integrator's additional margin on the racking and as this represents a significant proportion of projects, it can add to a negative ROI

"Offering a 2D shuttle and racking combined from the same company certainly helps. But what we found, which may be an issue, is that those suppliers are really just suppliers, not integrators. The integrators will add a lot of margin. I mean, they have their standard margin, but also put it on a lot of the steel which makes a 2D shuttle project more expensive than it needs to be. This is not related to labor cost for the integration but they add 10-15% on the steel with no value, in our view. But you need an integrator as soon as you do more than pallet in/out. That's also an issue." [Anonymous 3PL]

USING LESS STEEL OR MINIMIZING SYSTEM INTEGRATOR MARGIN ON RACKING COULD IMPROVE ROI



Source: STIQ Ltd Research & Analysis

3PL CONSIDERATION: RE-USE OF EQUIPMENT

- 3PLs have more considerations to include in a potential automation project than looking at efficiency improvements and also must consider residual value, automation reusability and the final customer, etc.

"Of course, we look at residual value, and this also depends on the proposition to the customer what we do. Your question is rather if we can use it for a second customer afterwards? Then, because that's not the book value but the actual value that you have. Because if you have a book value but no customer for it, then you can also write it off. So the reusability, we don't consider this yet, because we don't know what will be in 10 years and whether we then have also a customer that needs a seven-deep channel solution or a 10-deep channel solution. Also, yeah, I don't know yet. I don't think that, that I will get through because we currently have a case, and we are not looking at this because we would like our customer to cover this remaining value." [Anonymous 3PL]

- Pallet storage solutions tend to be dedicated to a single customer's requirements and the reusability (currently) may be limited

"Pallet ASRS is still a dedicated or specialized setup. It's not like a general purpose storage solution. Because you're still designing it to your customer, to the exact pallet type you need. In a normal pallet racking, you can just adjust the beams for the next customer and there is a reusability for sure. But in this case, it's not so easy to do that. I don't think it's even possible. It's fit for your customer, and if the customer has only CCG1 pallets, you will do the perfect setup for this customer. If the next customer uses CCG2 pallets, then you can't use the system for the customer. And if you already planned it for CCG2, then you are not competitive for the first customer. So you're still in a dedicated, specialized solution. You can't just use it for any customer the way it is." [Anonymous 3PL]

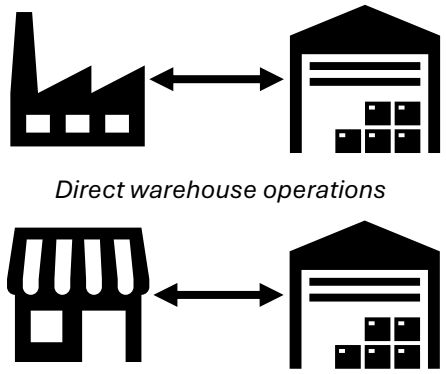
THE 3PL BUSINESS MODEL - RESELLING AUTOMATION TO THE FINAL CUSTOMER. CONTRACT LENGTHS AND CUSTOMER RELATIONSHIPS OFTEN INFLUENCE MHE DECISIONS

3PLs ARE ALSO SELLING TO THEIR CUSTOMERS

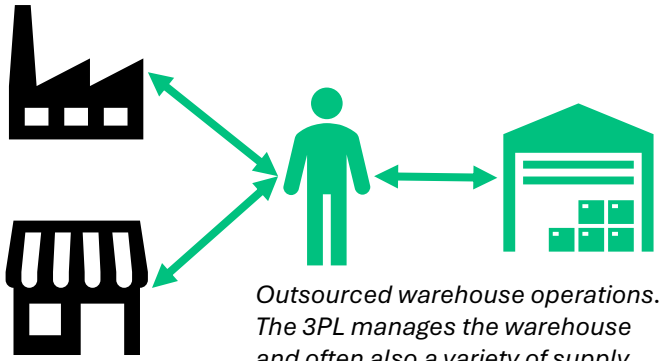
- 3PLs are a particular type of automation customer as they will often offer solutions to their fulfilment customers and touting a technology that is immature to an important customer could be detrimental to the larger relationship

"There's certainly preferred vendors in this space. We also looked at cost and maturity for the different vendors. On one side are the cheap and often immature sides, often Chinese vendor, and on the mature and very expensive side, I had then other vendors... European vendors. But we don't have a full overview and I still have big question marks on some of the Chinese vendors. Can I now go to the market and sell their solution? Typically, we can't go to the big FMCG brands and tell them, 'hey, we found someone for 10% less cost.' But no one has a warehouse with them, but let's do it. Of course when you have a 10-year relationship with a customer you don't want to be concerned about the technology vendor and whether or not they will exist in 10 years time. That's also something that I need to consider in solution design. With this shuttle system, it's also not so easy to do a POC. With lower-cost mobile robots you can just say, 'Okay, bring me 10 robots and I try it for 10 weeks, and then I take them back.' You can't just install a pallet ASRS and try it out for free. You really need to have a case. Getting the steel in and everything like that... it's not really a POC kind of situation. This also makes it also harder to adopt a solution. If there are also big price differences, you always ask twice - how can it be?" [Anonymous 3PL]

AUTOMATION CALCULATIONS ARE DIFFERENT FOR A 3PL COMPARED TO COMPANIES MANAGING THEIR OWN WAREHOUSES (SIMPLIFIED)



Direct warehouse operations



Outsourced warehouse operations. The 3PL manages the warehouse and often also a variety of supply chain tasks for customers

Source: STIQ Ltd Research & Analysis

IMPORTANCE OF SOFTWARE

- Software functionality is paramount for 2D shuttles, especially to manage larger fleets in a roaming situation where it is possible to use lifts to flood a single level, etc. to increase throughput

"For 2D shuttles, pallet in/out, software is not very important... everyone can do it. For anything else, software becomes super important. But in general, software is very important because you need to optimize the movements and you can reduce the number of shuttles needed. I'm sure everyone has some logic for full pallet movements and so on. But once you get into layer or case picking, then software becomes super important, and that's also where integrators matter a lot more." [Anonymous 3PL]

EUROPEAN VENDORS IN THE LEAD (IN EUROPE)

- European vendors appear to have an advantage in Europe based on the higher volume of reference locations

"There's no lack of reference sites from the European vendors especially in FMCG space." [Anonymous 3PL]

THE 2D SHUTTLE HAS FOUND A NICHE/WHITE SPACE AND MAY REPLACE PART OF THE CRANE MARKET. FEW OTHER ALTERNATIVES AVAILABLE NOW

THE 2D SHUTTLE REPLACING CRANES?

- It is likely that shuttles will replace cranes (as in the tote based fulfillment segment), especially as there are fewer and fewer limits for deployments

"I would say shuttles will replace cranes... because these are also dedicated long-term setups, and the shuttle can go as high and has better density. Well, with this mother-child concept on the crane, but this is even more specific. I think 2D shuttles is potentially a good replacement for cranes in the future. To my knowledge, these shuttles can go higher... 25 meters perhaps. A vendor mentioned that they can go to 30m." [Anonymous 3PL]

- The throughput of a shuttle system is faster compared with a crane, but this often depends on the configuration

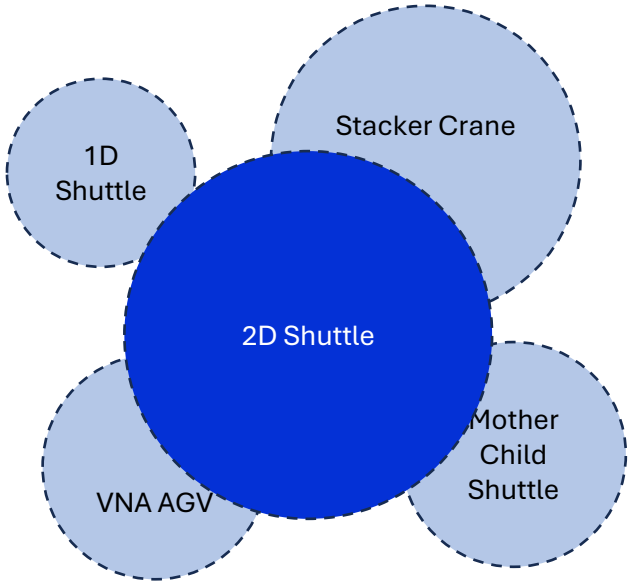
"I would say that a pallet shuttle is faster than a crane. Because you can have a shuttle on every level. With a crane you're stuck with one crane per aisle." [Anonymous 3PL]

- Cranes often require specialist flooring concrete slabs which can make them unsuitable for 3PL operations, often with more standard warehouses

"I don't remember a case with crane solutions in the last 2-3 years. Also, the groundwork is so extreme. Cranes are interesting if you can go really high. We operate a couple of these solutions but we are not designing them so often." [Anonymous 3PL]

- However, there are plenty of inhibitors to overcome for the 2D shuttle before it will completely replace cranes

2D SHUTTLE OVERLAPPING WITH LEGACY TECHNOLOGIES AND WHITE SPACE



Source: STIQ Ltd Research & Analysis

"For me, to be a Big Mac of course, you need to have a certain status in the market. Shuttles will replace crane solutions in my view, but they don't replace all the manual pallet solutions. They will not be at 2,000 installations like one cASRS vendor in a few years, so it's not so easy to get there... and in this business it takes time." [Anonymous 3PL]

THE VNA AGV IS NOT A REALISTIC OPTION

- Autonomous VNAs are a potential alternative for 2D shuttles, but these are most likely suitable for limited applications

"VNAs are an option to 2D shuttles. But this depends on the case as well and what kind of business it is. In theory the AMR VNAs are an option, but not in practice. I still haven't seen it and I don't see that it will take over for vertical handling for the moment. I haven't seen operations with 200 pallets in and out for this type of technology. If you have and if you run 24/7 it's 5 pallets an hour maybe. We looked at this multiple times but never found it being competitive." [Anonymous 3PL]

THE 1D SHUTTLE OPTION HAS ITS NICHE

- The 1D shuttle is a hybrid manual-automated solution which could be an option and there are new entrants from Asia in this space too

"The 1D shuttle is established and should have a wider acceptance. We also looked into this, and there are now some Chinese vendors also stepping into 1D shuttles. But they also need to build up some trust with us because many of them didn't have stable overseas organizations... I expect them to be very competitive from a pricing point of view. But the maturity of their systems is a big question mark. We will keep our eyes on this because we have connections with local vendors because we have strong connections to some racking suppliers." [Anonymous 3PL]

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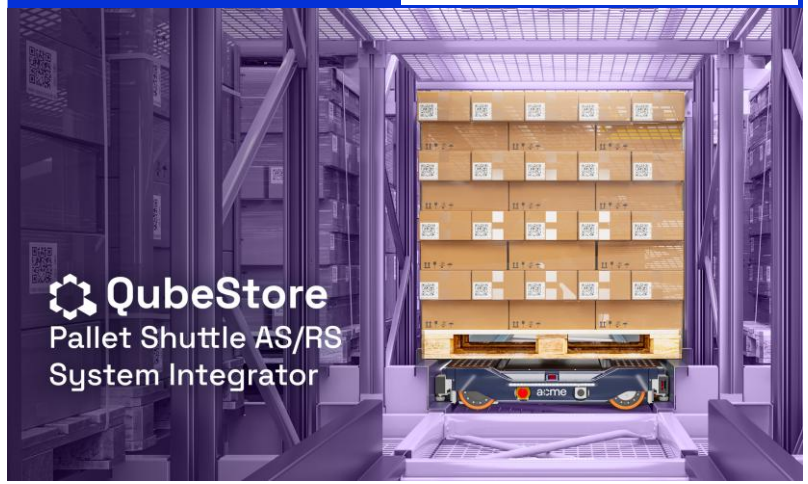


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PALLET AUTOMATION DIRECTORY: A-E

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Acme Intralog
AE | 1975



Addverb
IN | 2016
- System integrator

Aistorage
US | 2024
- 2D shuttle vendor

Alfatec
DE | 1994
- Crane vendor

armes
IT | 1956
- Crane vendor

Armstrong Dematic
IN | 1999
- System integrator

Automha
IT | 1979
- Pallet ASRS vendor
- Acquired by Comau in 2025

Bluesword
CN | 1993
- System integrator

Bullseye
CN | 2018
- Mother & Child shuttle vendor

Burns & McDonnell
US | 1898
- Consultancy

Cassioli
IT | 1943
- Crane vendor

Daifuku
JP | 1937
- System integrator

Dambach
DE | 1974
- Crane vendor

Eurofork
IT | 2000



DCS
US | 1982
- System integrator

Deliecn
CN | 2010
- Pallet ASRS vendor

EAB
SE | 1957
- 1D shuttle vendor

Equipment Depot
US | 1951
- System integrator

PALLET AUTOMATION DIRECTORY: G-M

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Galaxis
CN | 2014
- System integrator

Gebhardt Intralogistics
DE | 1952
- System integrator

Geek+
CN | 2015
- 2D shuttle vendor

GLOBL PTR
CN | 2007
- 2D shuttle vendor

Gonvarri Material Handling
NO | 1996
- Crane vendor

Hatmill
UK | 2009
- Consultancy

Hegerls
CN | 1996
- 2D shuttle vendor

Highbay AB
SE | 2016
- Maintenance provider

Hubmaster
ES | 2016
- Crane vendor

In&Out
IT | 2022
- 1D shuttle vendor

Inform
CN | 1997
- Crane vendor

Jaja Intelligent
CN | 2019
- Crane vendor

KEDE
CN | 2020
- Crane vendor

Korber Supply Chain
DE | 1946
- System integrator

Mecalux
ES | 1966



Magicrack
JP | 1973
- Pallet ASRS vendor

MGL
PL | 2007
- System integrator

Logiqs
NL | 1975
- 2D shuttle vendor

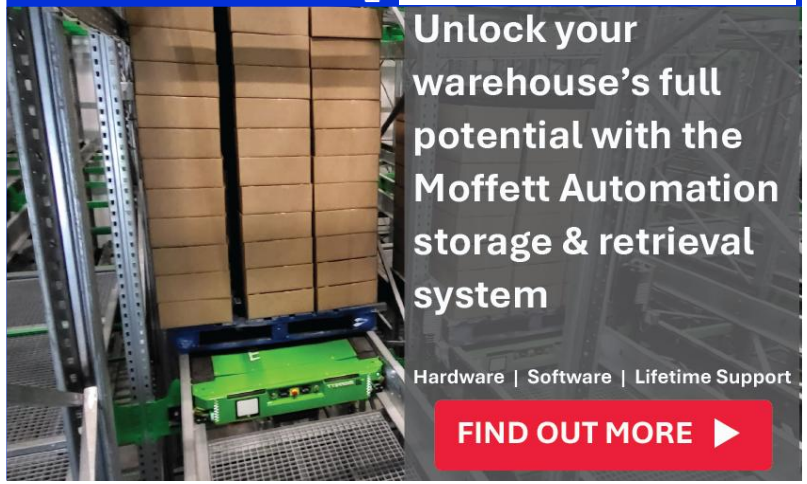
Matco
NL | 1977
- Pallet wrapping vendor

MIAS
DE | 2013
- Crane vendor

MPS Engineering
IT | 2014
- Crane vendor

PALLET AUTOMATION DIRECTORY: M-S

Moffett Automation
IE | 2017



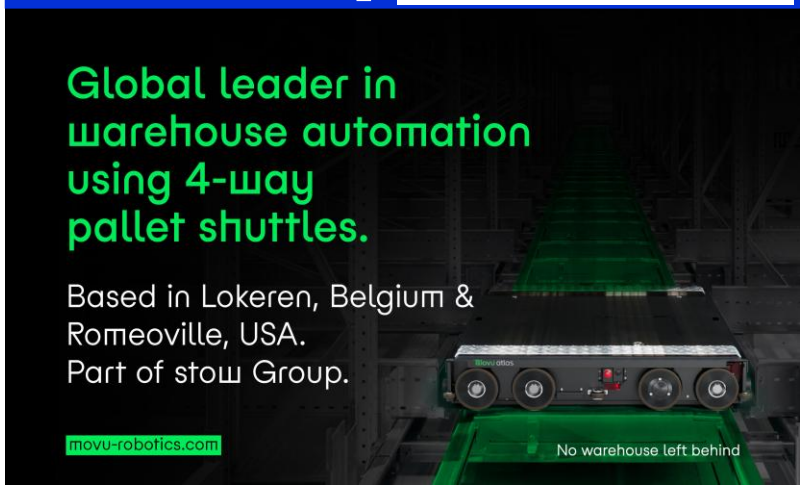
Mytra
US | 2022

- 3D shuttle vendor

NEDCON
NL | 1969

- Racking vendor
- Acquired by voestalpine in 2004

MOVU Robotics
BE | 2021



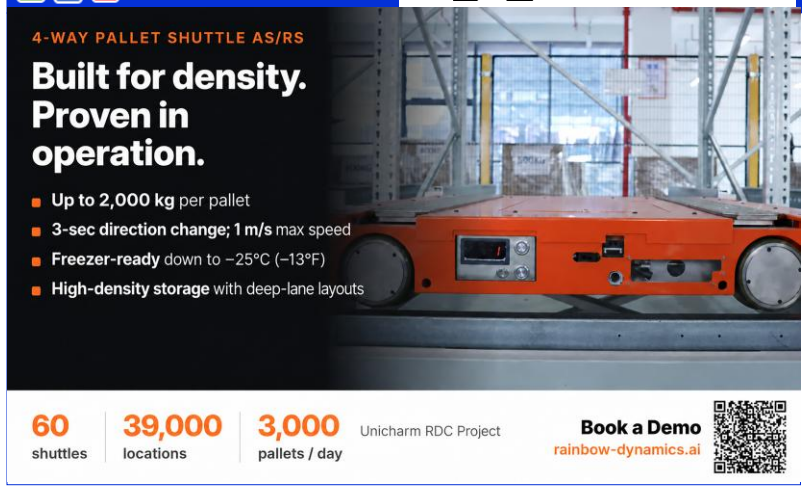
Nilkamal
IN | 1981

- Pallet ASRS vendor

Quicktron
CN | 2014

- 2D shuttle vendor

Rainbow Dynamics
UK | 2024



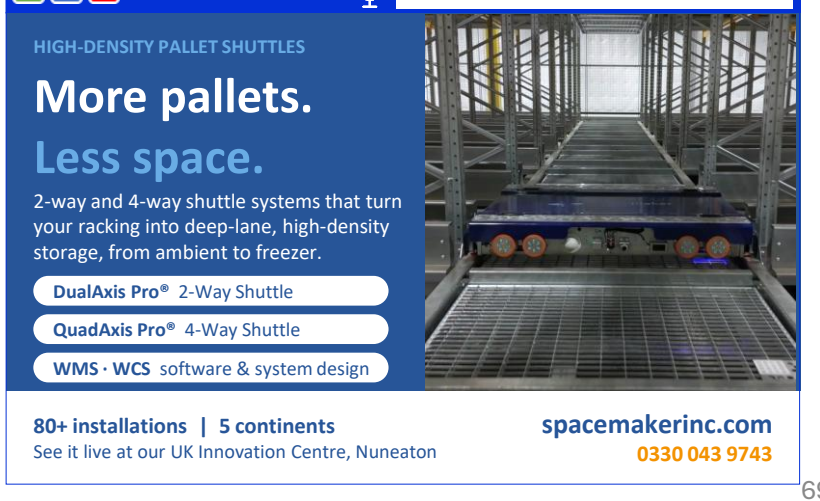
Redcrab
CN | 2020

- 2D shuttle vendor

SIBA
AT | 1999

- Crane vendor

Spacemaker Systems
UK | 2010



STAMH
BU | 2000

- Crane vendor

Steelking
US | 1970

- Racking vendor

PALLET AUTOMATION DIRECTORY: S-Z

Swisslog
CH | 1900

- Pallet ASRS vendor

TGW
AU | 1969

- System integrator

Toyota Automated Logistics
JP | 2001

- System integrator

Trascar
IT | 1973

- Crane vendor

Twinlode
US | 1981

- Crane vendor
- Acquired by KPI Solutions in 2022

Westfalia
DE | 1971

- Crane vendor

WDX
PL | 1995

- System integrator

Zending
CN | 2021

- 2D shuttle vendor

Zikoo
CN | 2017

- 2D shuttle vendor

ZS Robotics
CN | 2019



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"I enjoy the reports STIQ creates. We recently went through an integrator assessment to define partners, and the report had a lot of good insights. We also appreciated the view of the tiers of integrators, as that is how we are looking to establish and define when we use certain partners." [Engineering Director, Anonymous $bn's 3PL]

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CREDITS: INTERVIEWS, EVENTS AND GLOSSARY

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INTERVIEWED STAKEHOLDERS:

Acme Intralog (AE)	**CEO**
Addverb (IN)	CEO EMEA
AI Storage Solutions (US)	Director of Operations
Armstrong Dematic (IN)	POSITION
Automha (IT)	VP Marketing
Burns & McDonnell (US)	Dept Mgr, Distribution & Warehousing
DCS (US)	Principal, Solution Design
Deliecn (CN)	Marketing Director
Equipment Depot (US)	Head of Engineering & Implementation
Eurofork (IT)	**CEO**
Gebhardt Intralogistics (DE)	CEO
Geek+ (CN)	VP Product Strategy & Growth
Hatmill (UK)	Partner
Highbay AB (SE)	CEO
Korber Supply Chain (DE)	Sales Director
Logiqs (NL)	CEO
Matco International (NL)	Manager Sales
Mecalux (ES)	**Marketing Director**
MGL (PL)	Director of R&D Department
MIAS (DE)	CEO NA
Moffett Automation (IE)	**CEO**
MOVU Robotics (BE)	**CSO**
Mytra (US)	CEO, Co-founder
NEDCON (NL)	Head of Business Development
Rainbow Dynamics (UK)	**CEO**
Spacemaker Systems (US)	**Managing Director, UK & Europe**
Steelking (US)	Head of Engineering
Swisslog (DE)	Pallet Solution Owner
Toyota Automated Logistics (NL)	Manager Solution Engineering
WDX (PL)	CEO
Zikoo (CN)	Overseas Sales Manager
ZS Robotics (CN)	**Overseas Sales Director**

ANONYMOUS CONTRIBUTORS:

- A few stakeholders requested to remain anonymous and STIQ is very grateful for their valuable contributions
- If you wish to participate in a STIQ report but prefer to remain anonymous, please simply let us know; We receive many incoming inquiries from a wide range of stakeholders with comments on our range of reports

TRADE SHOWS & EVENTS VISITED

Automate (Chicago, US)	Website
Automation Taipei (Taipei, TW)	Website
Cemat Asia (Shanghai, CN)	Website
LogiMAT (Stuttgart, DE)	Website
Logis-Tech Tokyo (Tokyo, JP)	Website
Modex, (Atlanta, US)	Website
NRF Big Show, (New York, US)	Website
NRF Europe (Paris, FR)	Website
Parcel & Post (London, UK)	Website
ProMAT, (Chicago, US)	Website
SiTL, (Paris, FR)	Website
STIQ Robotics (London, UK)	Website
The ARC (Oslo, NO)	Website

RE: '2D SHUTTLE' VERSUS '4-WAY SHUTTLE'

- Note that throughout this report we refer to **2D pallet shuttles**, also known as 4-way pallet shuttles
- We think this is a better explainer of the system as it moves in X + Z dimensions (2 dimensions)

GLOSSARY

1D Shuttle	1-Dimensional shuttle
2D Shuttle	2-Dimensional shuttle (aka 4-way shuttle)
3D Shuttle	3-Dimensional shuttle
3DM Shuttle	3-Dimensional shuttle + AGV/AMR
AMR	Autonomous Mobile Robot
AGV	Automatic Guided Vehicle
AS	Asia
ASRS	Automatic Storage & Retrieval System
B&M	Brick & Mortar (physical retail store)
CAGR	Compound Annual Growth Rate
CCG1/ CCG2	Standard pallet height (1.05m/ 1.95m)
CPG/FMCG	Consumer Packaged Goods (US/UK)
EOL	End Of Life
EU	Europe
F&B	Food & Beverage
G2P, GTP	Goods to Person
GTM	Go To Market
M&A	Mergers & Acquisitions
MHE	Material Handling Equipment
NA	North America
RAAS	Robotics As A Service
RCS	Robot Control System
ROI	Return On Investment
RPC	Robotic Pick Cell
SI	System Integrator
SMB/SME	Small & Medium Businesses (US / UK)
US	United States of America
VNA	Very Narrow Aisle (forklift)
WCS	Warehouse Control System
WES	Warehouse Execution System
WMS	Warehouse Management System