WAREHOUSE AUTOMATION

INDUSTRY PERSPECTIVES & THE PATH AHEAD

NOVEMBER 2021

QUINLAN &ASSOCIATES

Section 1

INDUSTRY OVERVIEW

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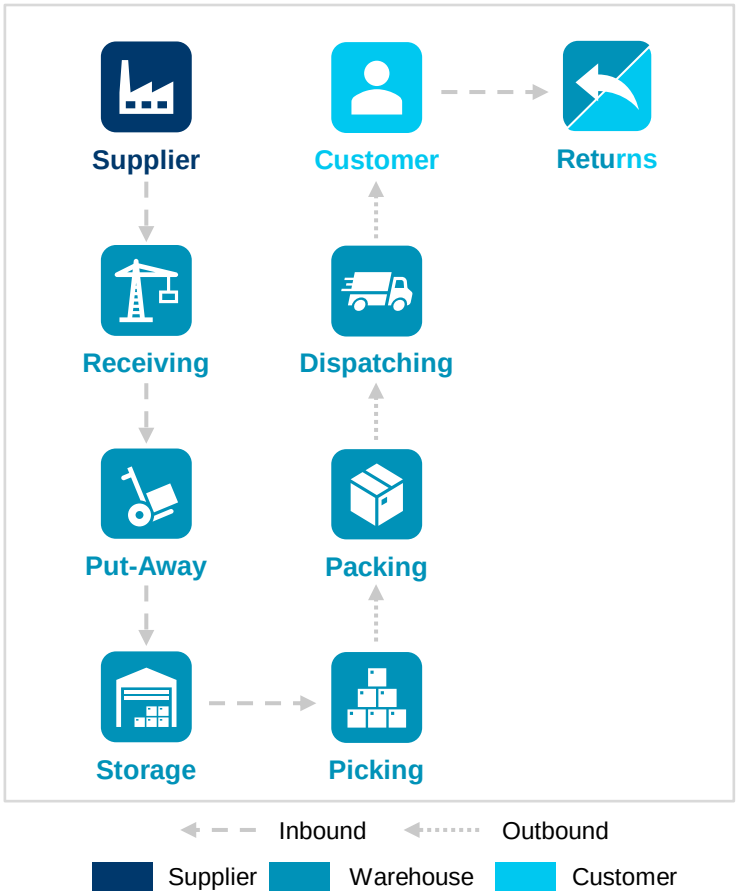
WAREHOUSE MANAGEMENT

Warehouse management consists of multiple processes that can potentially be automated, with the autonomous mobile robots market set to reach USD 6.7 billion by 2026

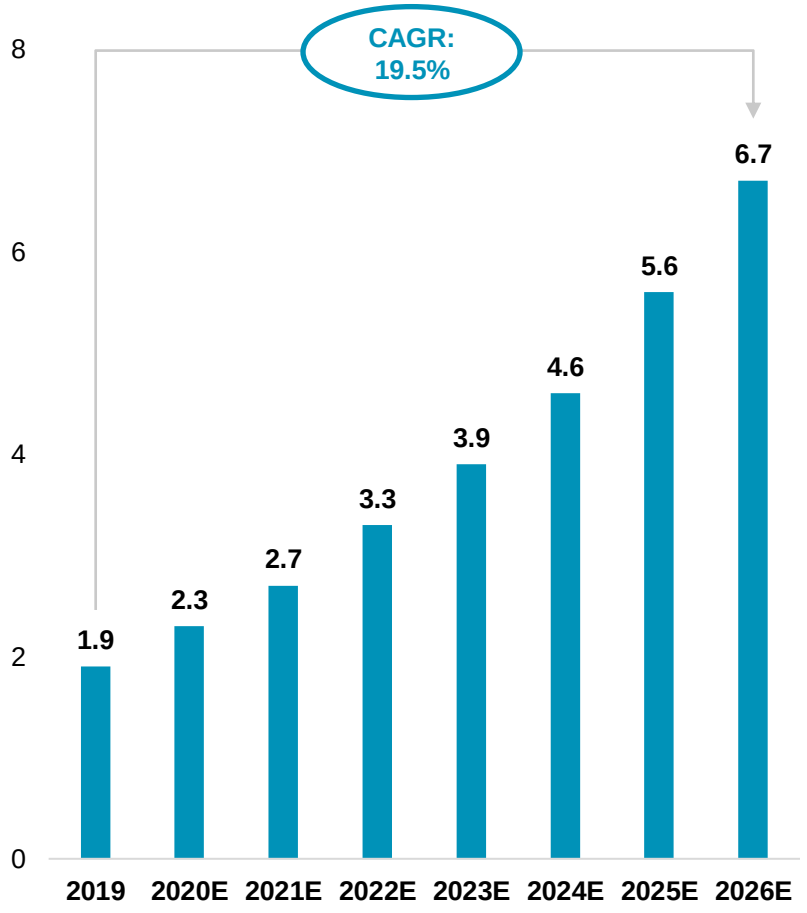
Warehouse Management

Process Flow



Autonomous Mobile Robots ("AMR")

Market Size, 2019-26E, USD Billion



Source: Grand View Research, GlobeNewswire, Quinlan & Associates estimates

PROCESS FLOW (1/6) – RECEIVING

There are five key steps in the receiving process: (1) inventory ordering; (2) appointment scheduling; (3) labour assignment; (4) stock unloading; and (5) goods inspection

Warehouse Management

Process Flow

	Description	Technology
INVENTORY ORDERING	• There are four main types of inventory: (1) raw materials / components, (2) work-in-progress ("WIP"); (3) finished goods; and (4) maintenance, repair, and operations ("MRO")	• An **inventory management system ("IMS")** uses automation through tracking technology like barcodes, radio-frequency identification ("RFID") tags, etc. to manage goods
APPOINTMENT SCHEDULING	• Appointment scheduling is a means for managing the timeliness of inbound and outbound transportation (i.e. truck traffic) at your loading docks	• **Dock scheduling software** can help automate a dock calendar, showing operating constraints, such as open / close time, commodities accepted through the dock door, etc.
LABOUR ASSIGNMENT	• For each stock of inventory arriving, a set of dock workers need to be assigned to be responsible for receiving the inventory	• A **labor management system** can provide productivity reporting and planning capabilities, helping optimise the assignment of dock workers
STOCK UNLOADING	• The warehouse dock workers are responsible for unloading the stock received, based on the appointment that they are assigned to	• Depending on the size and volume of the cargo, unloading sometimes requires **heavy lifting equipment** such as forklifts and pallet jacks
GOODS INSPECTION	• Upon receiving the goods, a thorough inspection is required, including the quantity, the integrity of seals, the product codes/SKUs, and the overall condition	• An **inventory scanner system**, based on barcode or QR-code scanning can help track the inventory received and feed the resulting data into the inventory management system

Source: Quinlan & Associates analysis

PROCESS FLOW (2/6) – PUT-AWAY AND STORAGE

There are four key steps in the put-away and storage process: (1) location selection; (2) goods organisation; (3) goods placement; and (4) inventory filing

Warehouse Management
Process Flow

	Description	Technology
LOCATION SELECTION	• Forming the hear of the put-away process, It involves the movement of goods from the dock to the most optimal warehouse storage location	• Using **AMR** for delivering the goods received to the most appropriate warehouse location is gaining popularity and can help optimise operations
GOODS ORGANISATION	• The goods received need to be organised in the most optimal manner, based on their quantity, size, and the nature of items involved	• A **warehouse slotting system** involves analysing inventory data to help categorise and organise the inventory, thereby helping maximise operational efficiency
GOODS PLACEMENT	• Placement is the warehouse process in which the goods received are placed into their most appropriate storage space, helping maximise the space that is available	• **Automated storage and retrieval systems ("ASRS")** can help automate the goods placement process, thereby reducing the need for human interaction
INVENTORY FILING	• The warehouse staff is also required to take charge of completing all documentation as well as inputting the received inventory's information	• An overall **warehouse management system ("WMS")** or an **inventory management system** may be used to keep track of the inventory

Source: Quinlan & Associates analysis

PROCESS FLOW (3/6) – PICKING

There are four key steps in the picking process: (1) methodology selection; (2) picker assignment; (3) methodology execution; and (4) transport station

Warehouse Management
Process Flow

	Description	Technology
METHODOLOGY SELECTION	• The optimal picking methodology is selected: (1) picker-to-goods; (2) picker-to-order; (3) cluster; (4) wave; (5) zone; (6) pick-and-pass; or (7) batch	• The aforementioned **WMS** can help guide on which picking methodology is most suitable, based on a variety of factors such as order volumes, inventory categories, etc.
PICKER ASSIGNMENT	• For each stock of inventory to be picked, a picker may need to be assigned to be responsible for picking the corresponding inventory required	• A **labor management system** can provide productivity reporting and planning capabilities, helping optimise the assignment of pickers
METHODOLOGY EXECUTION	• Once a methodology has been selected and a corresponding picket has been assigned, the methodology then needs to be implemented	• Several automated warehouse picking systems have emerged, such as **(1) pick-to-light; (2) voice picking; (3) mobile scanner; (4) AMR; (5) PA AMR; and (6) ASRS**
STATION SELECTION	• Once the inventory has been retrieved, it then needs to be transported to the most optimal packing station for conducting the next steps	• A **labor management system** can provide productivity reporting and planning capabilities, helping optimise the selection of a packing station

Source: Quinlan & Associates analysis

PROCESS FLOW (4/6) – PACKING

There are three key steps in the packing process: (1) container selection; (2) container packaging; and (3) container labelling

Warehouse Management

Process Flow

	Description	Technology
CONTAINER SELECTION	• Space and weight are key determinants for selecting a container that is small and light, but at the same time also sufficient to protect the finished item	• **Containerisation** has emerged as a process that utilises standardised containers for the storage and transportation of items from a warehouse
CONTAINER PACKAGING	• The items retrieved are then (1) packed; (2) wrapped; and (3) sealed with the container, ensuring that the goods are packaged safely and in good condition	• **Automated packaging systems** can help reduce the need for human labour in packaging of containers, thereby saving labour costs as well as eliminating any potential human errors
CONTAINER LABELLING	• Before a package is dispatched, it needs to be assigned a corresponding shipping label and invoice, in order to help facilitate its tracking at a later stage	• Containers often have **printed information, barcodes, and even RFID tags** on them, in order to help track their location and status

Source: Quinlan & Associates analysis

PROCESS FLOW (5/6) – DISPATCHING

There are five key steps in the dispatching process: (1) carrier selection; (2) package sorting; (3) stock loading; (4) package delivery; and (5) delivery verification

Warehouse Management

Process Flow

	Description	Technology
APPOINTMENT SCHEDULING	• Appointment scheduling is a means for managing the timeliness of inbound and outbound transportation (i.e. truck traffic) at your loading docks	• **Dock scheduling software** can help automate a dock calendar, showing operating constraints, such as open / close time, commodities accepted through the dock door, etc.
PACKAGE SORTING	• The packages that need to be delivered are sorted at the loading dock in the most appropriate manner in order to increase loading efficiency	• **AMR** can be utilised for automating the sorting process for packages that have been kept at the loading station, thereby helping avoid any cluttering
STOCK LOADING	• Upon the arrival of the carrier, the stock needs to then be loaded in the back of a truck and may involve the use of heavy lifting equipment	• **Automated guiding vehicles ("AGVs")** are self-guided and can include forklifts and pallet carts, which follow digital paths throughout the facility to load stock
PACKAGE DELIVERY	• After the stock is loaded onto the truck, the packages are finally delivered by the carrier to the intended location and customer	• Warehouses may track the delivery of a package through **order tracking technology**, that allows them to check the real-time status of a package
DELIVERY VERIFICATION	• Warehouses may need to verify the coherence of a delivery, in order to ensure that the right package has been delivered to appropriate customer and location	

Source: Quinlan & Associates analysis

PROCESS FLOW (6/6) – RETURNS

There are four key steps in the picking process: (1) return order creation; (2) goods inspection; (3) disposition deliberation; and (4) decision processing

Warehouse Management

Process Flow

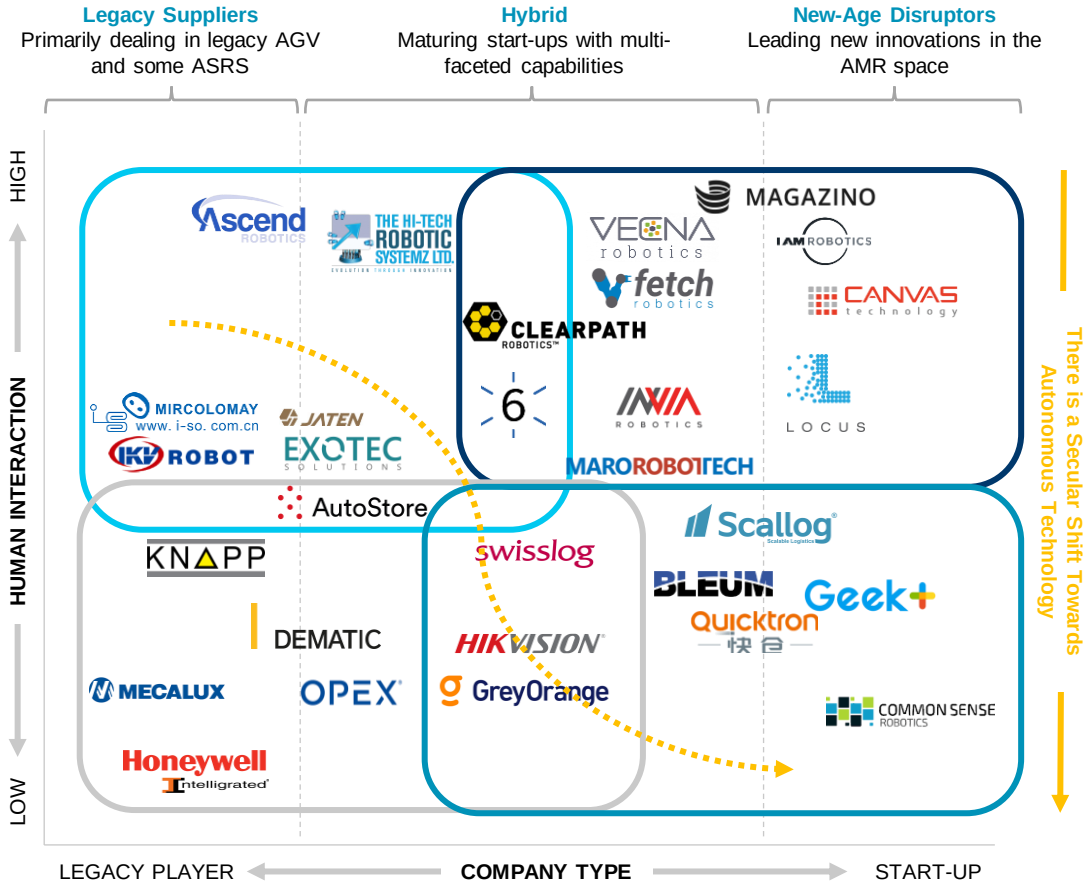
	Description	Technology
RETURN ORDER CREATION	• Upon receiving a complaint or request from a customer for an item to be returned, a “Return Management Authorisation” should be crafted	• A **returns management system** may help create a more streamlined process for handling customer returns and complaints
GOODS INSPECTION	• Upon the receiving the returned goods, they need to then be inspected by the warehouse staff for any damage or other shortcomings, as reported by the customer	
DISPOSITION DELIBERATION	• A decision needs to then be taken on what should be done with the goods, e.g. return to stock, repair, destroy, discard, recycle, return to manufacturer, etc.	
DECISION PROCESSING	• After a decision is taken, the inventory system should be updated based on whether the goods are returned to stock, or are held for further action	

Source: Quinlan & Associates analysis

COMPETITIVE LANDSCAPE

There are four primary player groups in the warehouse automation landscape: (1) AGV; (2) AMR; (3) PA AMR; and (4) ASRS

Competitive Landscape
Key Player Groups



Key Player Groups
AGV, AMR, PA AMR, and ASRS

Group	Description
AGV	Portable robots that use marked long lines / wires on the floor, radio waves, vision cameras, magnets, or lasers for navigation
AMR	A vehicle that uses sensors and processors to autonomously move materials without the need for physical guides or markers
PA AMR	A type of AMR used to augment the picking system by guiding a human picker to the location of the inventory to be picked
ASRS	Computer-controlled systems that automatically place and retrieve loads from set storage locations in a facility

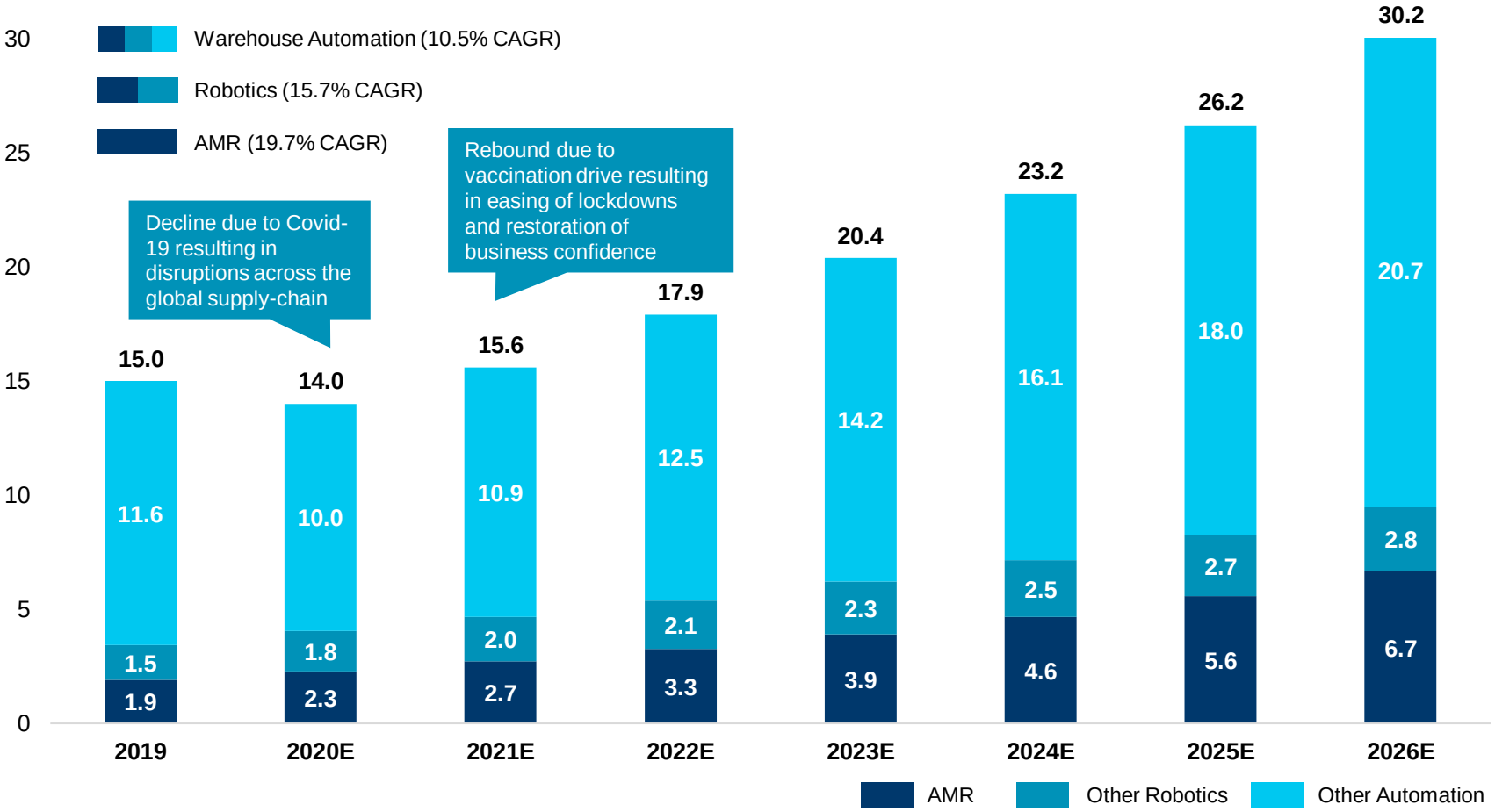
Source: StyleIntelligence, Quinlan & Associates analysis

MARKET OPPORTUNITY (1/4) – GLOBAL

The global warehouse automation market is expected to reach USD 30.2 billion by 2026, growing at a CAGR of 10.5%, with the AMR market touching USD 6.7 billion

Global Market Opportunity

2019-26E, USD Billion

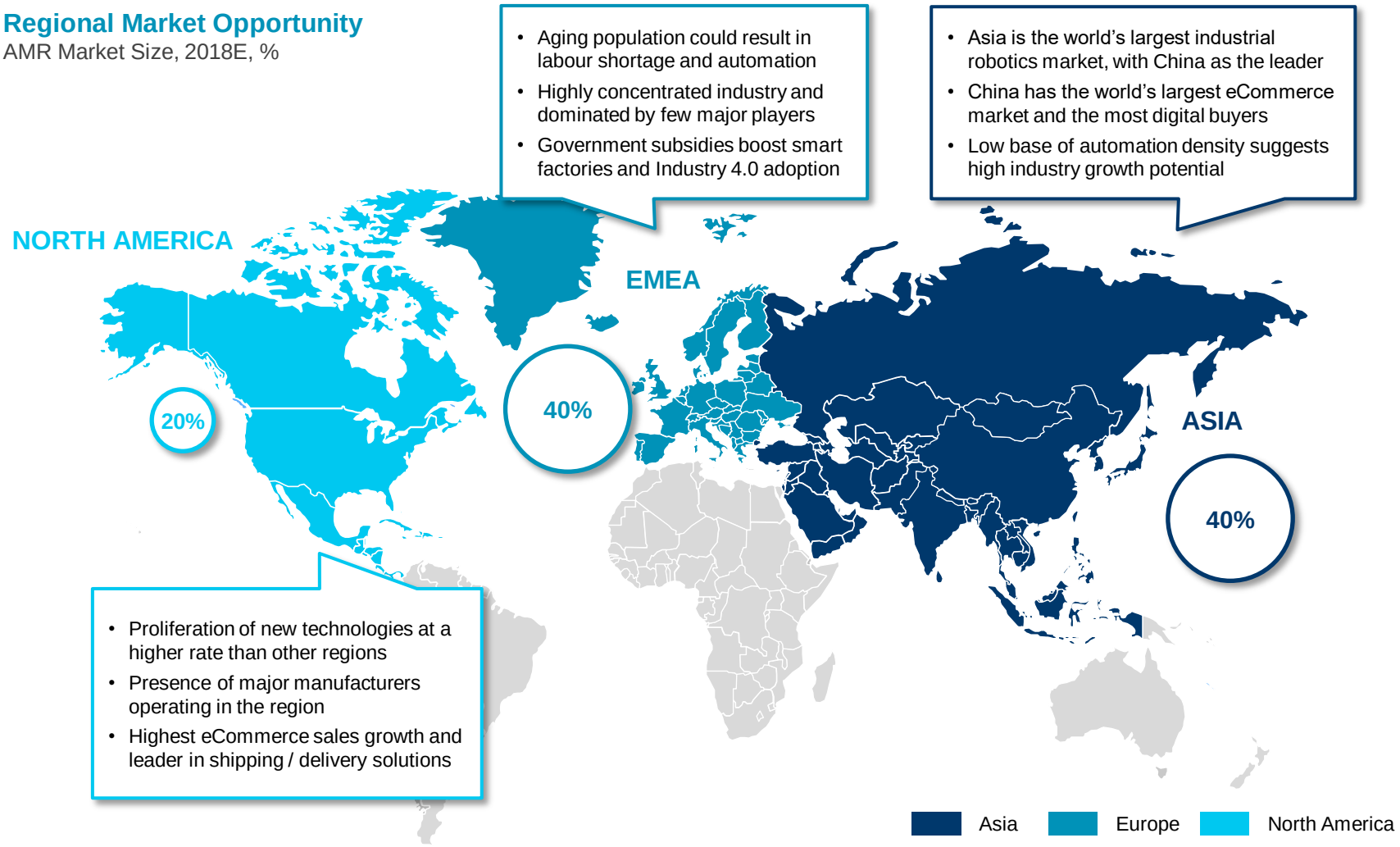


Source: Statista, Grand View Research, GlobeNewswire, Quinlan & Associates estimates

MARKET OPPORTUNITY (2/4) – REGIONAL

Asia has emerged as a key growth region for the AMR market, with China in particular showcasing robust potential

Regional Market Opportunity
AMR Market Size, 2018E, %



- Aging population could result in labour shortage and automation
- Highly concentrated industry and dominated by few major players
- Government subsidies boost smart factories and Industry 4.0 adoption

- Asia is the world's largest industrial robotics market, with China as the leader
- China has the world's largest eCommerce market and the most digital buyers
- Low base of automation density suggests high industry growth potential

- Proliferation of new technologies at a higher rate than other regions
- Presence of major manufacturers operating in the region
- Highest eCommerce sales growth and leader in shipping / delivery solutions

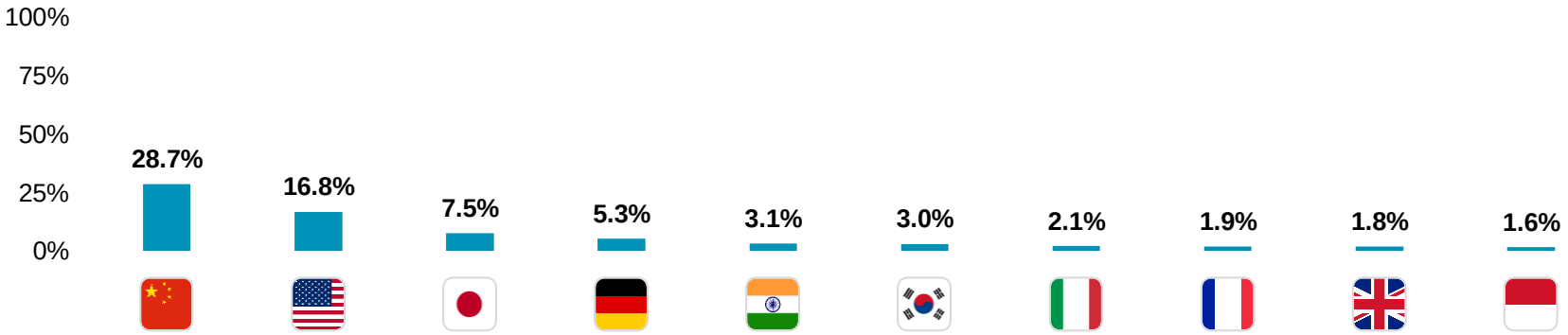
Source: STIQ, Quinlan & Associates estimates

MARKET OPPORTUNITY (3/4) – MANUFACTURING ACTIVITY

While China continues to be the global leader in manufacturing, several other countries in Asia have also seen rapid growth in their industrial output, opening new AMR opportunities

Manufacturing Output

Share of Global Manufacturing Output, 2019, %



Key Asian Manufacturing Hubs of the Future

Growth Drivers by Country

Country	India	Bangladesh	Laos	Indonesia	Vietnam
Growth Drivers	*The "Make in India" policy and recent Production Linked Incentive (PLI) scheme have added to India's low labour costs and rich abundance of raw materials*	*With wages increasing in other countries, Bangladesh is fast emerging as a low cost alternative in labour-intensive industries like ready-made garments*	*Laos has begun to tap into its rich reserves of natural resources at a faster pace, with economic activity picking up rapidly, and a wave of foreign investment entering the country*	*The availability of vast swathes of workers in Indonesia has led to increase in exporting of unprocessed natural resources and simple manufactured goods*	*With geopolitical risks concerning manufacturers in China, Vietnam is fast emerging as an alternative due to its cheap cost, stable politics, and liberalised policies*

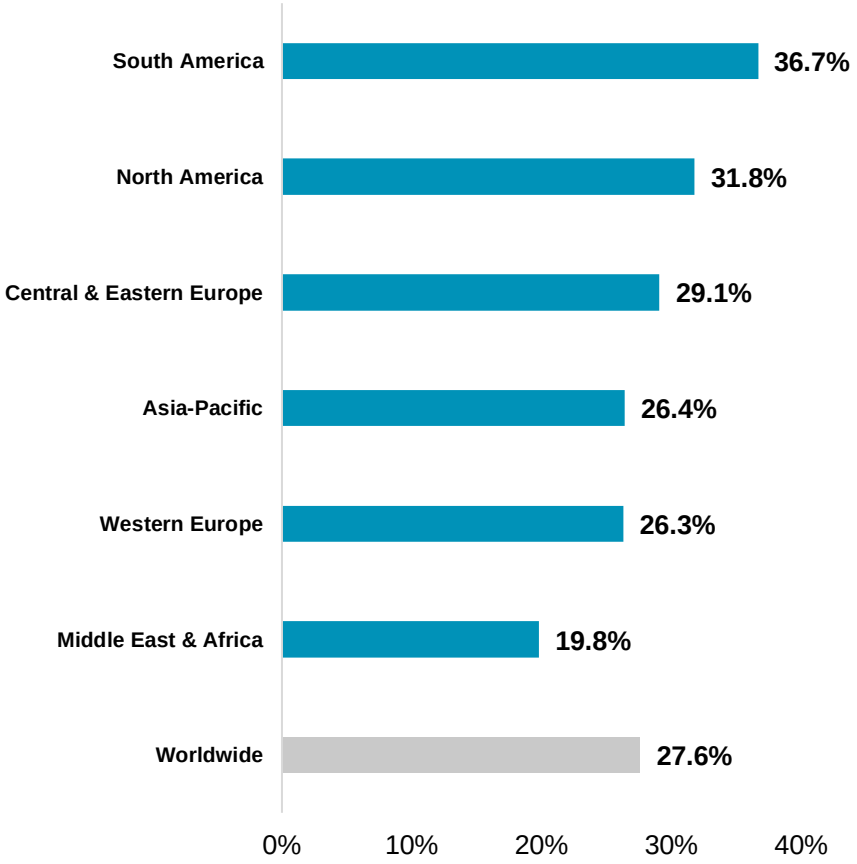
Source: World Bank, Statista, CEIC, Trading Economics, Quinlan & Associates estimates

MARKET OPPORTUNITY (4/4) – ECOMMERCE ACTIVITY

eCommerce remains a key driver of manufacturing activity, with the Americas exhibiting the strongest growth rates, though China still remains the leading market by far

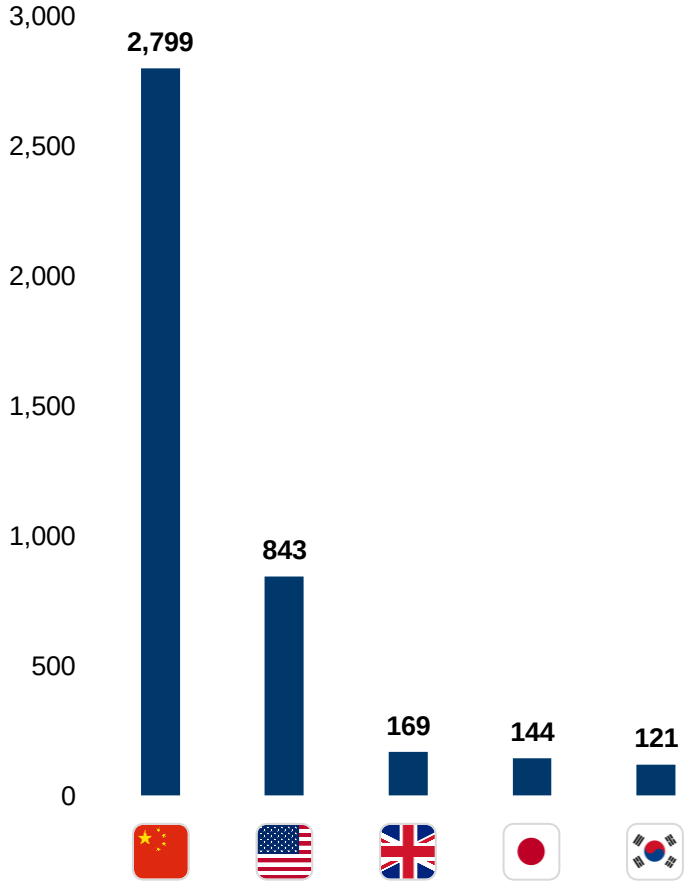
Key Regions

Retail eCommerce Sales Growth, 2020, %



Key Countries

eCommerce Sales, 2021E, USD Billion



Source: eMarketer, Quinlan & Associates estimates

TECHNOLOGY (1/2) – HARDWARE

There exist several key types of hardware that are being utilised by different players across the warehouse management lifecycle

Technology
Hardware

	RECEIVING	PUT-AWAY	STORAGE	PICKING	PACKING	DISPATCHING	RETURNS	DESCRIPTION
Automated Forklifts	✓	-	✓	✓	-	✓	-	Used to load and unload inventory
Aerial Vehicles	-	✓	✓	✓	-	-	-	Perform checks and transport goods
Automated Guided Carts	-	✓	-	✓	-	-	-	Transport goods via predefined tracks
Unit Load Vehicles	-	✓	-	✓	-	-	-	Used for transporting goods
Tugger Vehicles	-	✓	-	✓	-	-	-	Used for transporting goods
Pick & Place Robotic Arms	-	✓	-	✓	-	-	-	Used for picking and placing inventory
Mobile Rack GTP[1]	-	✓	-	✓	-	-	-	Used for transporting goods
Roaming Shuttle	-	✓	-	✓	-	-	-	Used for transporting goods
Various Types of ASRS	-	-	✓	✓	-	-	-	Used for storing and retrieving inventory
Bot Sorter	-	-	✓	-	-	✓	-	Used for sorting goods
Collaborative Bots / PA AMR	-	-	-	✓	-	-	-	Used to aid human pickers

✓ Applicable

[1]Goods-to-Person
Source: Quinlan & Associates analysis

TECHNOLOGY (2/2) – SOFTWARE

Software-focused offerings are on the rise, but there remains a shortage of modular offerings for plug-and-play use

Technology
Software

	RECEIVING	PUT-AWAY	STORAGE	PICKING	PACKING	DISPATCHING	RETURNS	ROLE
ERP[1] Software	✓	✓	✓	✓	✓	✓	✓	Business administration
WMS Software*	✓	✓	✓	✓	✓	✓	✓	Governs inventory movement, storage
WES Software	✓	✓	✓	✓	✓	✓	✓	Used for managing flow of inventory
WCS Software	✓	✓	✓	✓	✓	✓	✓	Real-time activities management
Inventory Mgmt. System	✓	✓	✓	✓	-	-	✓	Specifically for tracking inventory
Labour Mgmt. System	✓	-	-	✓	✓	✓	-	Specifically for tracking labour
Dock Scheduler	✓	-	-	-	-	✓	-	Specifically for scheduling dock
Slotting System	-	-	✓	-	-	-	-	Specifically for optimising slotting
Container. Software	-	-	-	-	✓	-	-	Specifically for selecting containers
Order Tracking	-	-	-	-	-	✓	-	Specifically for tracking dispatches
Returns Mgmt. System	-	-	-	-	-	-	✓	Specifically for coordinating returns

✓ Applicable

[1]Enterprise Resource Planning
Source: Quinlan & Associates analysis

BUSINESS MODEL (1/2) – HARDWARE

The popularity of RaaS[1] is on the rise, as smaller eCommerce traders emerge, custom development remains expensive, and demand fluctuation hampers direct purchase

Business Model

RaaS, Custom Development, and Direct Purchase

		1 LEASE RaaS	2 BUILD Custom Development	3 BUY Direct Purchase	
	DESCRIPTION	A subscription / renting / leasing-based service, that is priced based either on time or usage frequency	An end-to-end customised development process, tailored to the client's personalised requirements	A one-time purchase of the end-use robotic equipment / machinery by the warehouse	
	CRITERIA				IMPACT
WAREHOUSE	AFFORDABILITY	✓	✗	-	Flexible credit / payment terms
WAREHOUSE	FLEXIBILITY	-	✓	✗	Flexible renewal options
WAREHOUSE	PERSONALISED	-	✓	✗	Tailor-made offerings
VENDOR	SCALABILITY	✓	✗	-	Standardised sets of robots
VENDOR	PRICING POWER	✓	-	✗	Differentiated solutions
VENDOR	STICKINESS	✓	✗	-	Recurring revenue focus
		The popularity of RaaS is on the rise	*Custom development is on the wane*	*Direct purchase is no longer a preferred option*	

Growing shift towards RaaS ✓ Favourable - Dependent / Neutral / N.A. ✗ Unfavourable

[1]Robot-as-a-Service

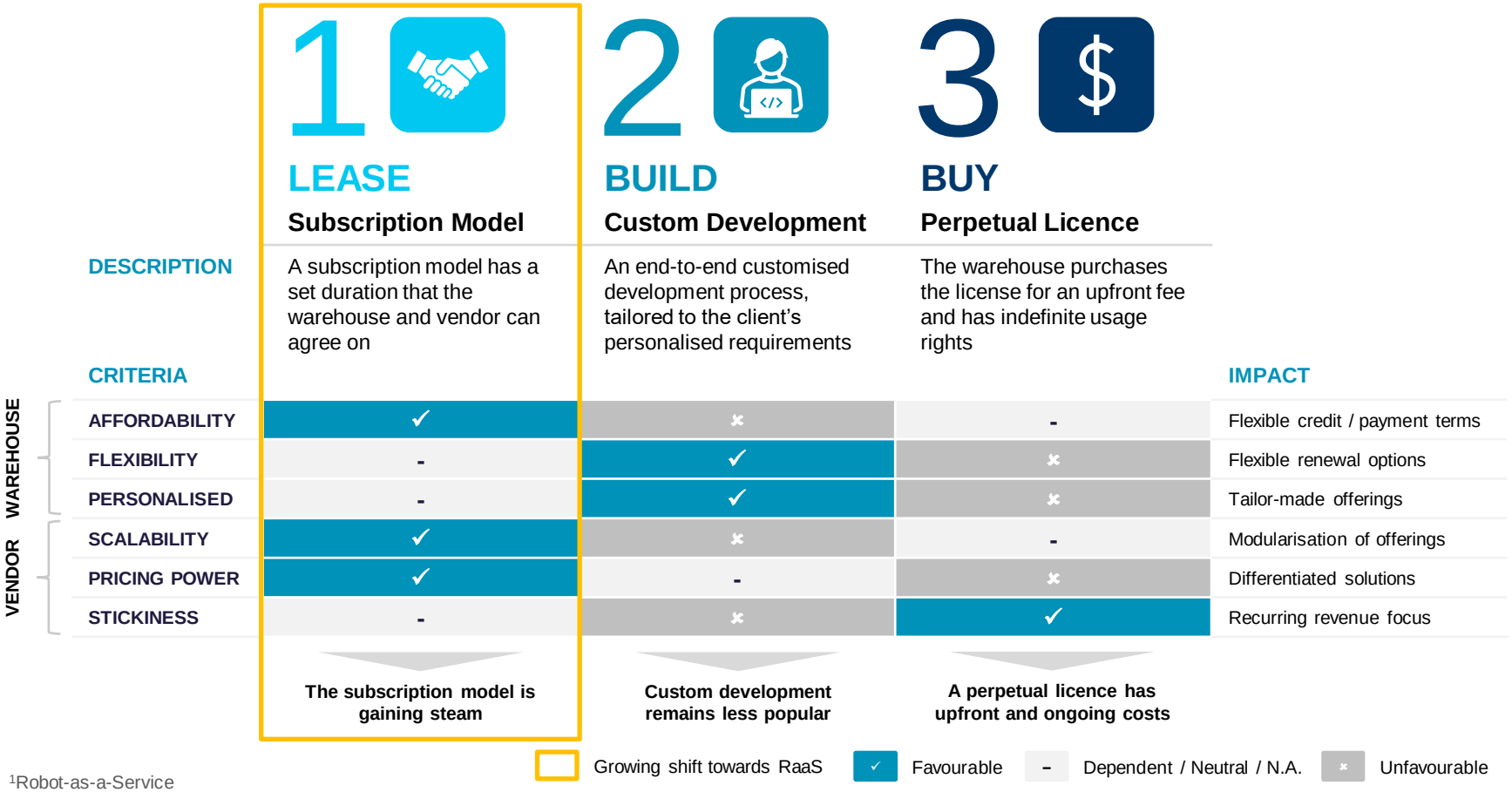
Source: Quinlan & Associates analysis

BUSINESS MODEL (2/2) – SOFTWARE

Owing to the relatively more flexible payment and renewal terms offered by subscription models, there is a shift away from perpetual licensing deals for software

Business Model

Subscription Model, Custom Development, and Perpetual Licence



[1]Robot-as-a-Service

Source: Quinlan & Associates analysis

Section 2

CHALLENGES & OPPORTUNITIES

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INDUSTRY TRENDS (1/2) – TAILWINDS

Companies may look to pursue software modularisation in developed markets, while opting for wearable technology to boost labour productivity in less developed markets

Tailwinds
Supporting Factors

Tailwind	Description	Expected Impact	Recommendation
Warehouse Software	• Companies are looking to better integrate and more efficiently manage the various processes and operations that take place in a warehouse	■ ■ ■ ■ □	• May look to enhance software offerings and **pursue modularisation** to provide more flexibility to warehouses
Robotic Automation	• In a bid to cut reliance on employees, warehouses are aggressively pursuing robotic automation as a means to slash costs	■ ■ ■ ■ □	• Apart from various forms of robotic automation already outlined earlier, **aerial vehicles** could emerge as the next big offering
Wearable Technology	• Warehouses are turning towards wearable technology to support human warehouse workers in tasks	■ ■ ■ ■ □	• In regions with cheap labour, such as India, Cambodia, etc., companies can offer wearable technology to **boost labour productivity**
Big Data	• Big data is helping warehouses understand layout utilisation and inventory placement, helping optimise how each square inch is used	■ ■ ■ □ □	• Companies may double down on their software offerings, by adding functionalities such as **inventory and layout optimisation**
Cloud Computing	• The growing use of technology in warehouses is being accompanied by a consequent adoption of cloud computing	■ ■ ■ ■ □	• Companies can explore **partnerships with prominent cloud providers** to further enrich their cloud-based offerings proposition
Internet of Things (“IoT”)	• The use of IoT is enabling warehouses to improve the traceability of their inventory, through interconnected sensors, RFID tags, etc.	■ ■ ■ ■ □	• The provision of IoT can help companies **provide modular services** such as inventory tracking, etc.

Low ■ ■ □ □ □ **High**

Source: Quinlan & Associates analysis

INDUSTRY TRENDS (2/2) – HEADWINDS

In order to capitalise on the headwinds facing the warehouse industry, companies needs to double down on their software and IoT offerings

Headwinds
Key Challenges

Tailwind	Description	Expected Impact	Recommendation
Inaccurate Inventory	• Inaccurate inventory may cause improper stock levels and a build-up of obsolete inventory, leading to picking problems	■ ■ ■ ■ □	• Companies may build-out their arsenal of software offerings that are focused on **inventory optimisation**, as a modular software offering
Suboptimal Picking	• Poor picking can potentially result in a disruption to the overall inventory control framework, leading to a domino effect	■ ■ ■ ■ □	• Companies should provide **AMR solutions in developed markets and IoT ones in emerging economies**, based on labour costs
Poor Space Utilisation	• Inadequate storage space as well as inefficient use of available spaces are common problems in warehouses with poor facility layout	■ ■ ■ ■ □	• Companies may double down on their software offerings, by adding functionalities like **layout organisation**, helping improve space utilisation
Demand Fluctuation	• There may be high levels of fluctuation in demand, which can wreak havoc on warehouses if they have an inventory imbalance	■ ■ ■ □ □	• By adding more inventory-focused software solutions, companies may help provide **demand forecasting**, integrated with its inventory robots
High Labour Costs	• Warehousing is a labour-intensive industry, employing large swathes of people, with social distancing regulations now also in place	■ ■ ■ ■ □	• In more developed markets with high labour costs, companies can **offer a robust suite of AMR** offerings to help cut labour costs for clients
Quality Control	• Ensuring the good quality of the inventory, right from receiving to dispatching is very important, to prevent a spike in customer returns	■ ■ ■ □ □	• **A holistic WMS offering** can help track quality control throughout the end-to-end inventory management value chain

Low ■ ■ □ □ □ **High**

Source: Quinlan & Associates analysis

RECOMMENDATIONS

We see significant room for improvement for warehouse robotics companies in the following three types of areas: (1) strategic; (2) operational; and (3) financial

Recommendations

Strategic, Operational, and Financial

STRATEGIC	CUSTOMERS	• Customer segmentation, with identification of key target customers
	CHANNELS	• Sales cycle streamlining, with a view to shorten / scale the overall sales process
	OFFERINGS	• Identification of demand drivers vis-à-vis specific products and service offerings
	GEOGRAPHIC	• Identifying new markets with high growth potential and calibrating market entry strategies
	PARTNERSHIPS	• Shortlisting of potential partners with robust synergies and differentiated value addition
OPERATIONAL	SCALABILITY	• Gauging internal capabilities to scale offerings and client base
	HUMAN RESOURCES	• Talent management strategy, based on labour requirements and talent sophistication
	RISK MANAGEMENT	• Review of any operational risks that the company may have to potentially contend with
	REGULATORY COMPLIANCE	• Ensuring compliance with the latest regulations governing warehouse safety standards
	CORPORATE GOVERNANCE	• Management alignment and organisational oversight to streamline operations
FINANCIAL	REVENUE DRIVERS	• Identification of key revenue drivers, in terms of customers, offerings, and pricing power
	COST DRIVERS	• Identification of key cost drivers, e.g. staff costs, research and development ("R&D"), etc.
	PROFITABILITY	• Balance sheet optimisation and identification of key profitability drivers

Source: Quinlan & Associates analysis

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STRATEGY WITH A DIFFERENCE