

AMR PLAYBOOK FOR ENTERPRISE

OPERATIONS & TECHNOLOGY EDITION



CONTENT PAGE

AMR PLAYBOOK FOR ENTERPRISES OPS & TECH EDITION

- 1. From concept to implementation
- 2. A step-by-step guide to AMR success

PHASE

1

INTERNAL PLANNING & READINESS

- 1. Visualise your current operations
- 2. Identify pain points & define requirements
- 3. Choosing the use case
- 4. Devise high level timeline & plan
- 5. Site & infrastructure preparation

PHASE

2

VENDOR ENGAGEMENT & SOLUTION DESIGN

- 6. Vendor engagement
- 7. Designing how AMRs work day-to-day
- 8. SOP & training

PHASE

3

TRIAL, ACCEPTANCE & GO-LIVE

- 9. User acceptance test
- 10. Operational trial & performance tracking
- 11. Go-live

ANNEX & GLOSSARY

- A. AMR components
- B. Standards & resources
- C. Performance metrics
- D. Glossary

FROM CONCEPT TO IMPLEMENTATION

OBJECTIVE

This guidebook is a non-exhaustive decision-making resource and workflow template for managing Autonomous Mobile Robot (AMR) deployment projects. It provides guidance across each phase, from initial assessment to vendor selection to operational integration and go-live.

AUDIENCE

This guide is designed for project managers and implementation leads responsible for planning and delivering AMR deployments. It is particularly useful for organisations undertaking their first AMR implementation.

PERSONA



Senior leadership has committed to implementing an AMR solution to address operational challenges, such as warehouse logistics or facility cleaning. A **dedicated project manager** has been appointed to lead vendor engagement and implementation.

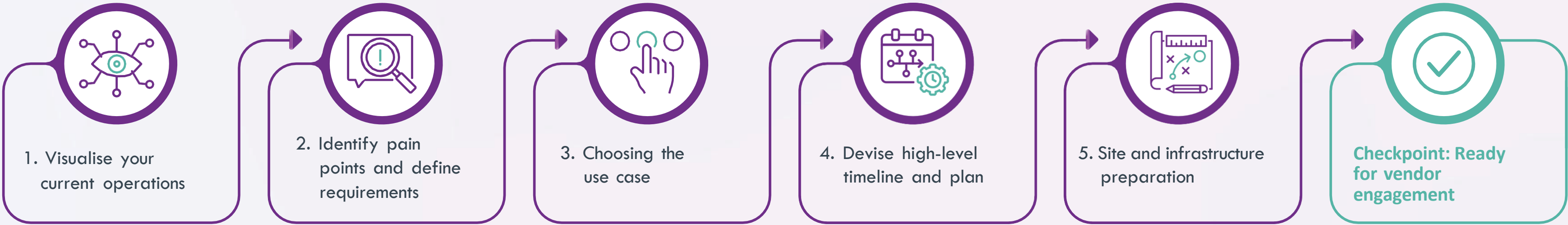
The **project manager's objective** is to achieve seamless deployment and integration of the AMR solution into existing operations, delivering measurable improvements in productivity, safety, and operational reliability.



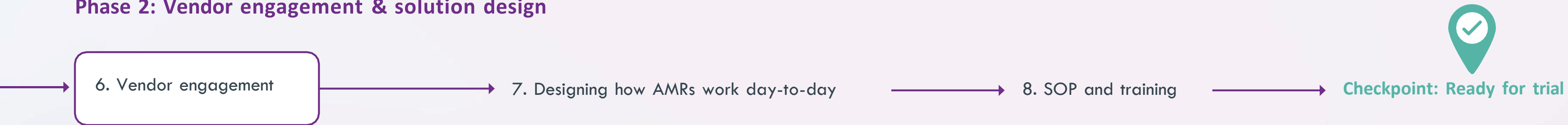
A STEP-BY-STEP GUIDE TO AMR SUCCESS

A step-by-step guide to enable project managers to facilitate internal preparation, vendor engagement and solution design, covering the journey from planning to go-live.

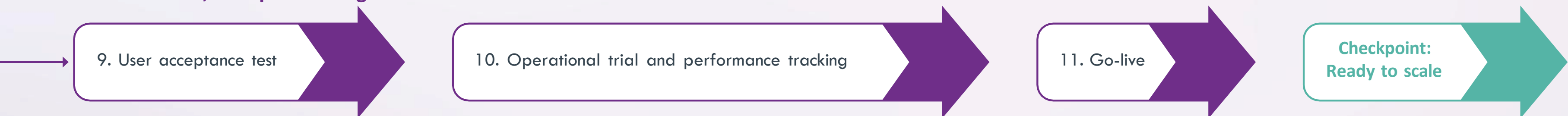
Phase 1: Internal planning & readiness



Phase 2: Vendor engagement & solution design



Phase 3: Trial, acceptance & go-live



GATE: READY TO ENGAGE VENDORS

At this stage, organisations should have a clear use case, baseline requirements, implementation timeline, and site preparation plan. These inputs support productive vendor discussions and solution design.

PROBLEM STATEMENT AND USE CASE

- Define the operational pain point, target workflow, deployment objective, and the business outcomes vendors are expected to respond to.

BASELINE REQUIREMENTS

- Set minimum scope across navigation environment, payload, uptime expectations, integration touchpoints, safety needs, and reporting requirements.

INTERNAL ALIGNMENT

- Confirm sponsor, operations owner, technical stakeholders, procurement or legal support and decision rights before external discussions begin.

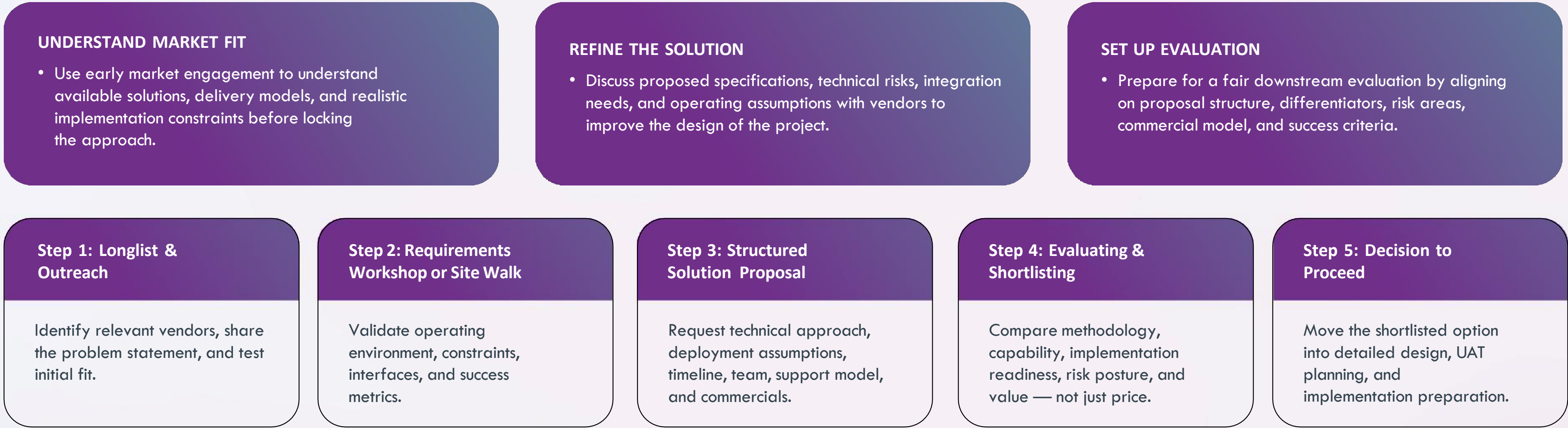
SITE AND IMPLEMENTATION ASSUMPTIONS

- Document current-state site constraints, infrastructure limitations, expected pilot area, timeline assumptions, and any known dependencies.



GATE: READY TO ENGAGE VENDORS

Early vendor engagement is recommended to communicate requirements, explore potential solutions, test risk allocation, and refine the procurement approach before formal bidding or commitment.

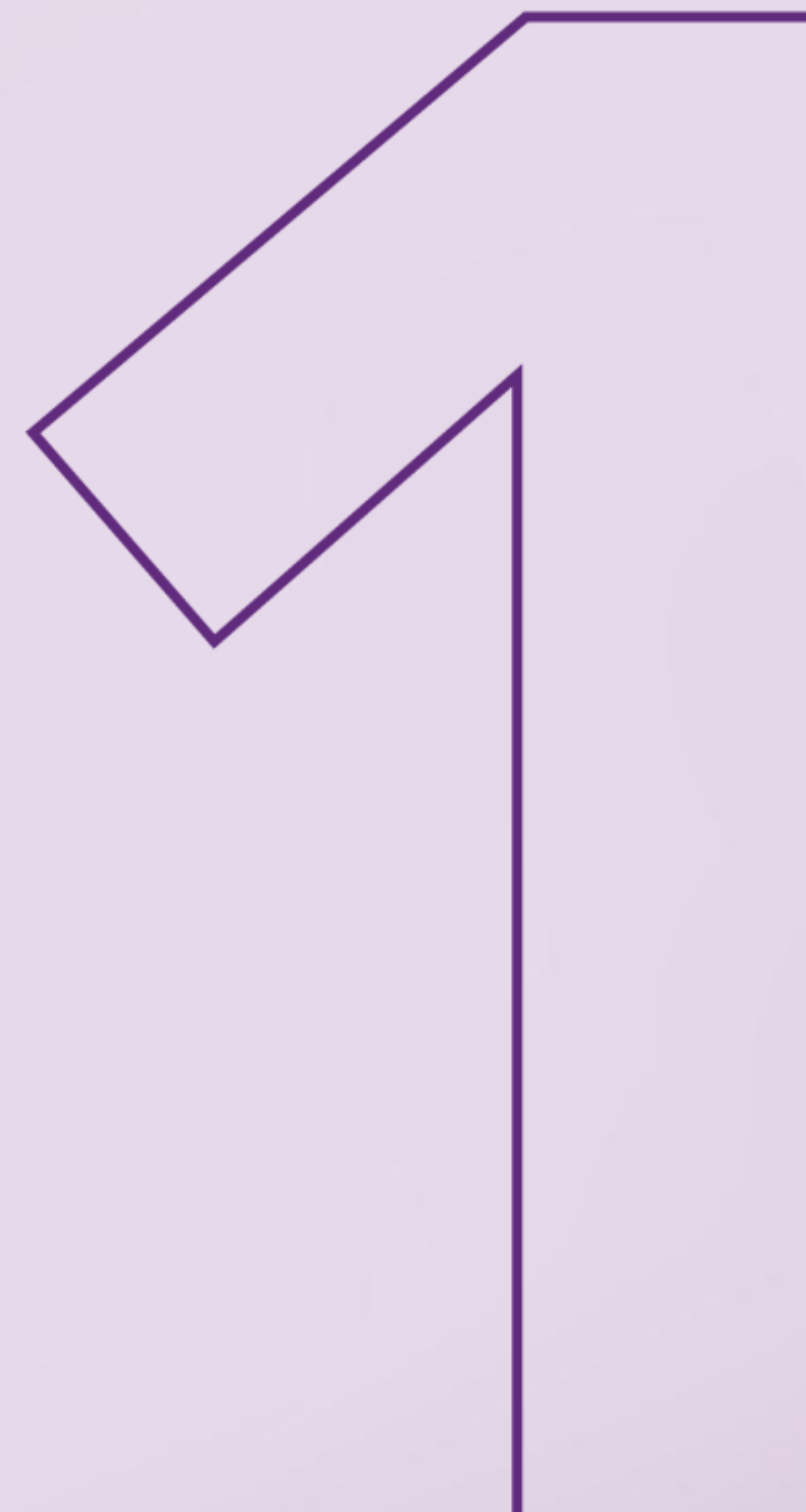




INTERNAL PLANNING & READINESS

This section helps project managers prepare for vendor engagement by documenting current operations, identifying operational pain points, and defining project goals, scope, and success metrics.

By grounding AMR initiatives in validated workflows and measurable business needs, it creates a clear foundation for vendor discussions and helps ensure decisions are aligned with operational needs.



1

VISUALISE YOUR CURRENT OPERATIONS

This phase maps current operations and processes to establish a clear understanding of the current state, forming the foundation for AMR adoption and operational changes.

What it includes:

- **Maps existing workflows end-to-end**, covering the flow of information, materials, and services.
- **Identify cross-functional connections** between departments and how they depend on one another.
- **Catalogue current systems, tools, and resources** used across processes earmarked for AMR transformation.

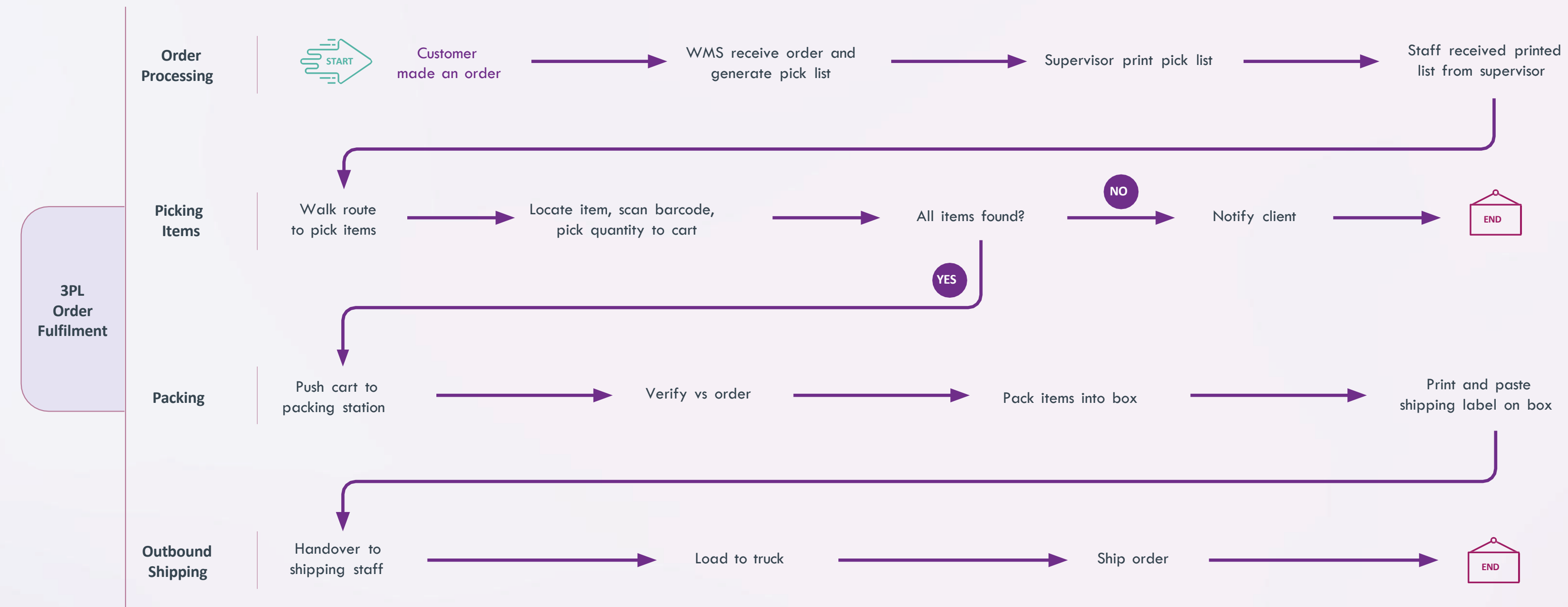
Why it's important:

- **Establishes a baseline** to measure future change and track the impact of AMR implementation.
- **Surfaces inefficiencies, bottlenecks, and repeatable tasks** to determine whether AMR is the right solution.
- **Aligns key stakeholders** on the current state, ensuring a shared understanding before changes are made.



VISUALISE YOUR CURRENT OPERATIONS

There are various methods for mapping and visualising operational processes. One effective approach is using a business process flow diagram. Consider the following example of a typical 3PL order fulfilment process.



2

IDENTIFY PAIN POINTS & DEFINE REQUIREMENTS

Using the mapped business process flow diagram, **conduct a systematic identification of key operational challenges requiring resolution**, including bottlenecks, excessive overtime, safety incidents or near-misses, and spatial constraints. This approach enables you to:

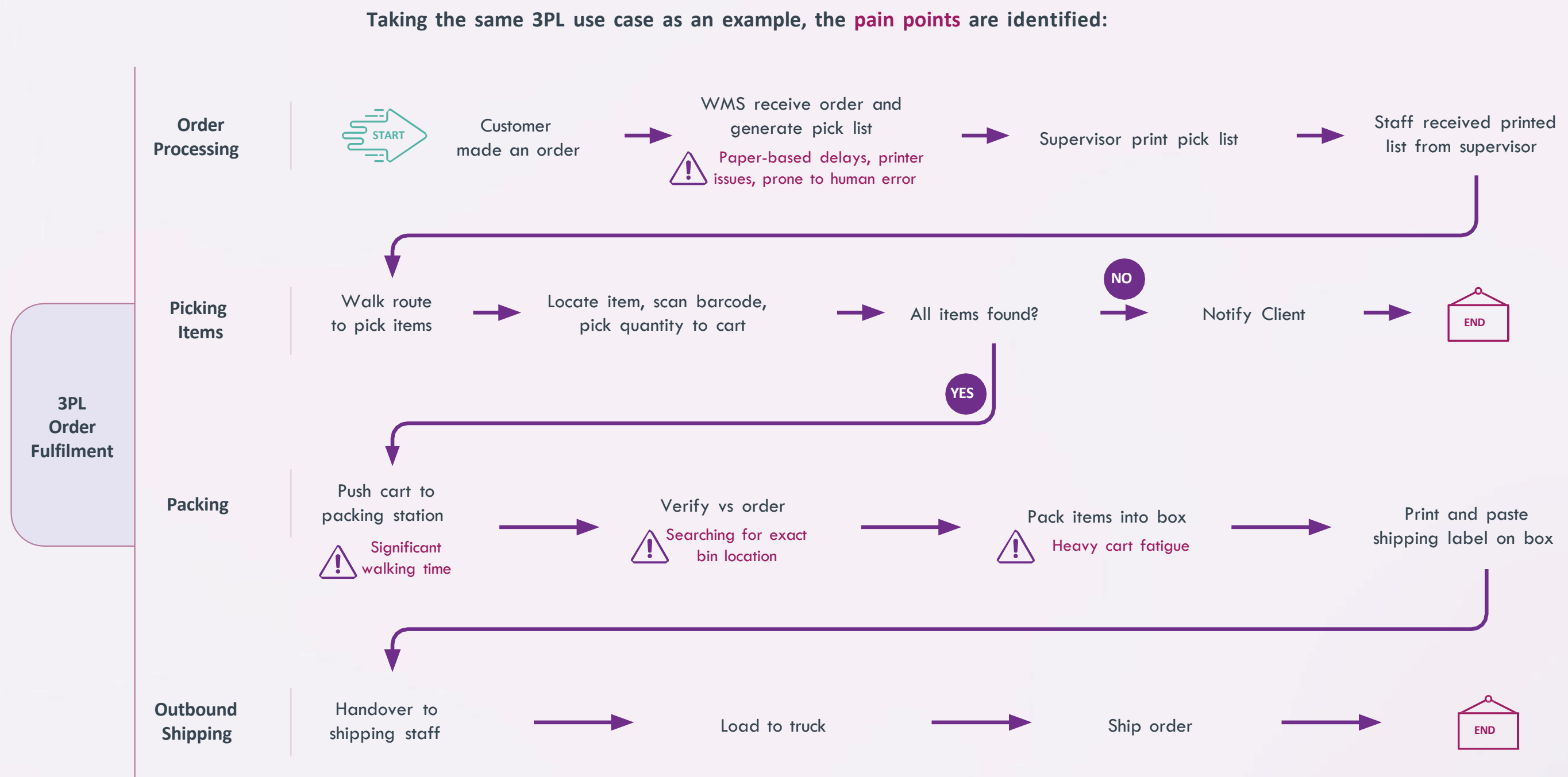
1. Prioritise improvement opportunities by impact on productivity, cost, and safety.

2. Set clear, measurable objectives tied to the most critical operational issues.

3. Design AMR use cases around real operational needs, not assumed problems

4. Identify affected roles to target training and change management.

5. Establish KPIs and benchmarks to measure post-deployment effectiveness.



2

IDENTIFY PAIN POINTS & DEFINE REQUIREMENTS

After identifying pain points in current operations, the next step is to define requirements, including project goals, scope, and success metrics. This step helps guide the team in solution scoping, ensures alignment, and supports decision-making.

1

PROJECT GOALS

- Define the business problem to be solved
- Set 3 clear goals (e.g., reduce manual trips, shorten lead time, improve safety)
- Align goals to identified pain points

2

PROJECT SCOPE

Define what is in scope and out of scope to ensure the team focuses on the right areas.

IN SCOPE

- On-site testing under normal, peak, and simple failure scenarios (e.g., blocked paths)
- Basic Wi-Fi assessment and charging station setup

OUT OF SCOPE

- Changes to ERP/WMS systems
- Process redesign outside AMR flows

3

SUCCESS METRICS

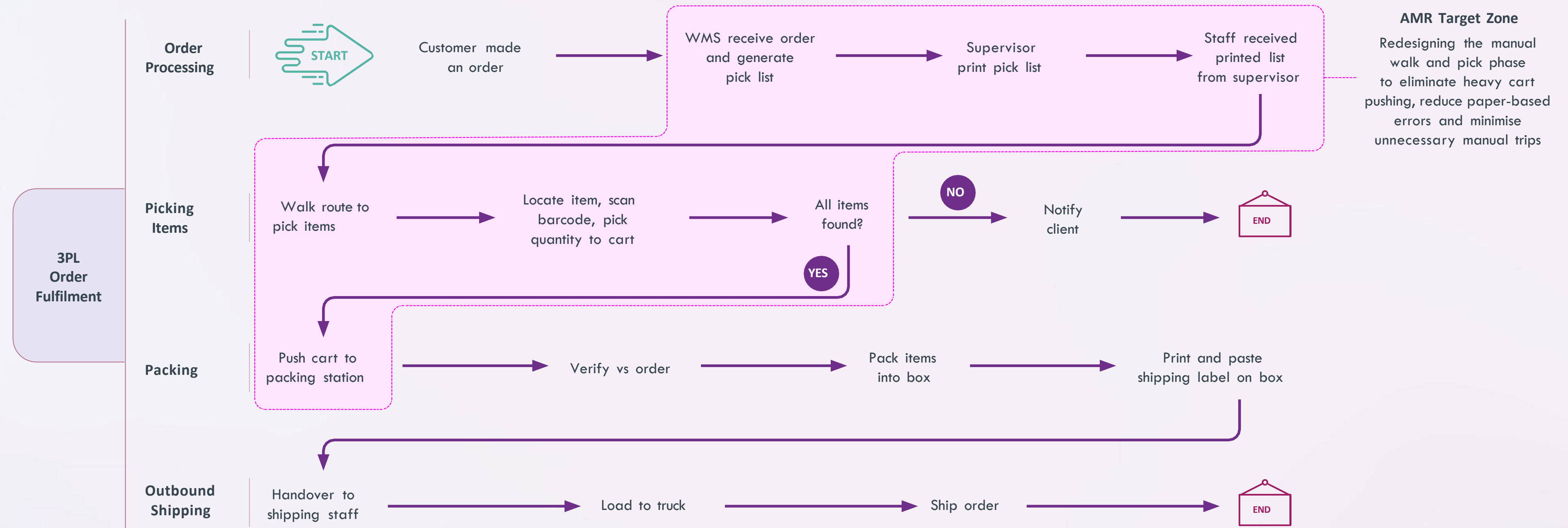
- Define objective KPIs to track progress against project goals
- Reduce subjective assessment at go-live
- Support management reporting and early issue identification

Examples:

Durability	Reliability	Feasibility
# of trips per day	# of trips successfully completed (average # of deliveries per day)	Average load per delivery
Average duration/travel time per delivery	# of anomalies/manual intervention required	# of man-hours/pax involved in operations
Average distance covered per delivery per day		Payback period
Average battery level drop		

3 CHOOSING THE USE CASE

Based on the mapped process and project goals, scope, and success criteria, you can **identify the first AMR use case**. The following 3PL order fulfilment example illustrates how pain points can be translated into KPIs and applied within the process.



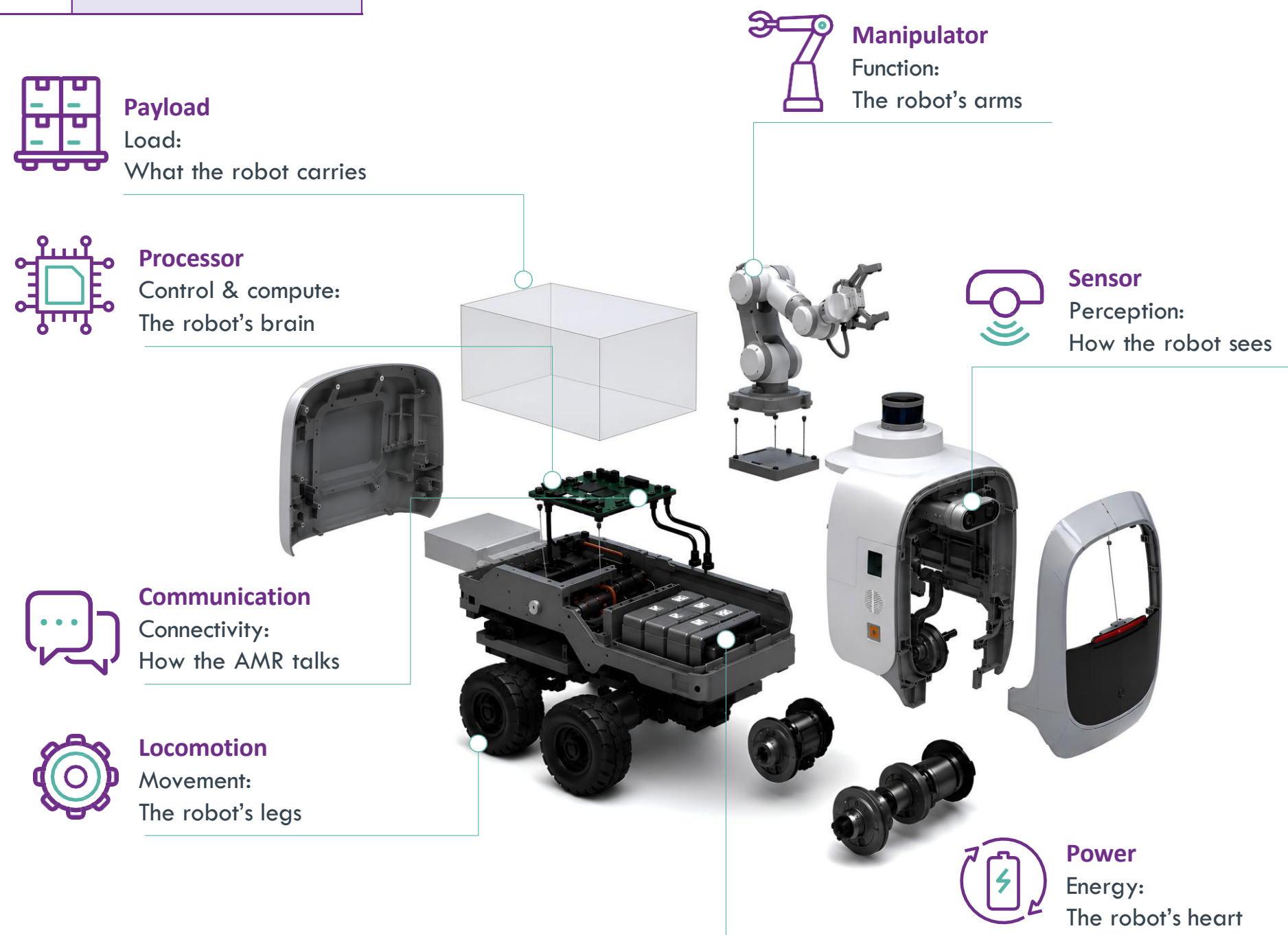
The subsequent pages provide AMR technical information to support the design of the to-be process with AMR. The to-be process is developed on a best-effort basis to facilitate discussions with AMR vendors.

3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

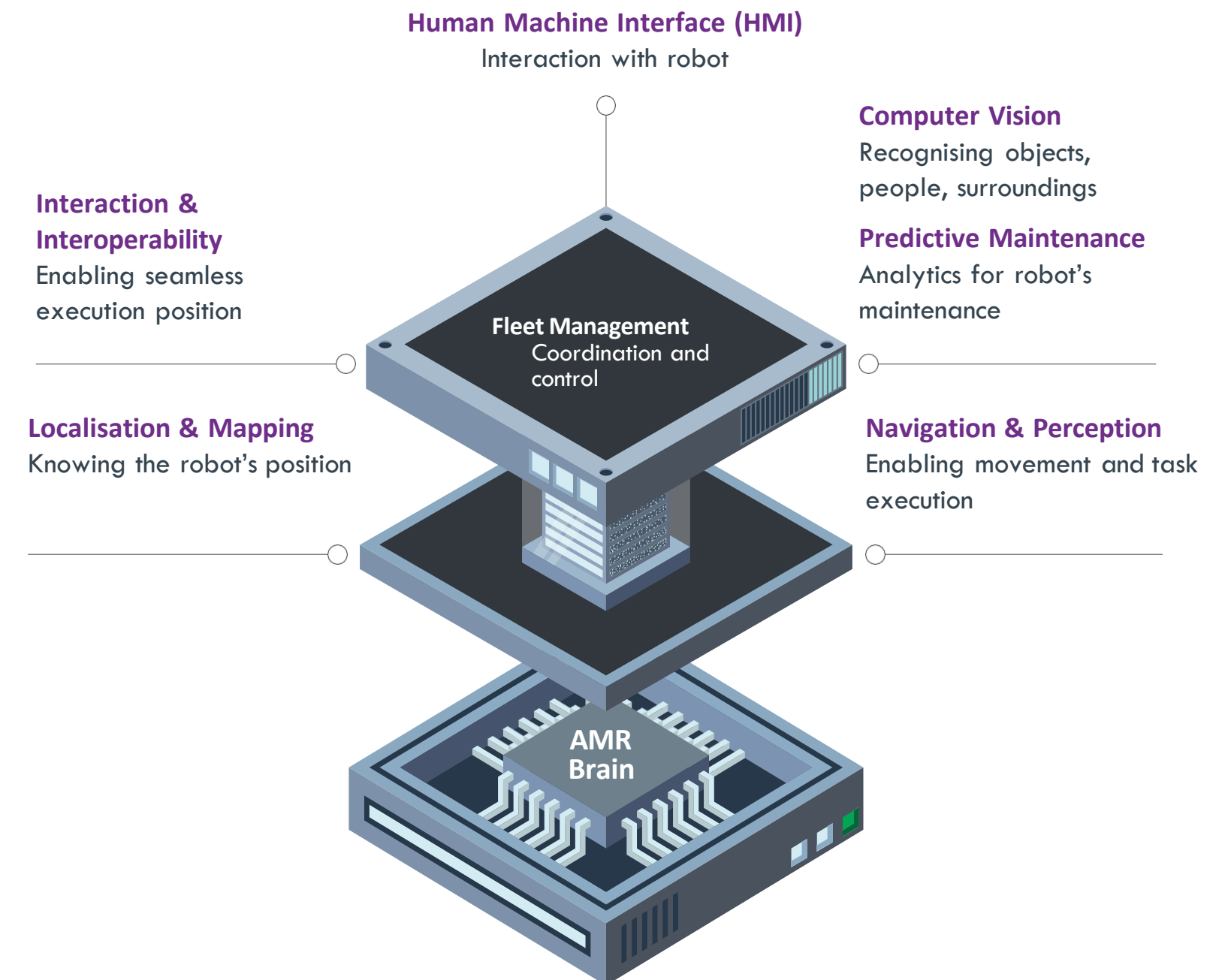
Designing an effective automated process starts with understanding AMR capabilities. This section outlines the key technical considerations that shape payload, movement, navigation, and system integration.

Hardware



Software

*See Annex A for the detailed technical components of an AMR



3 CHOOSING THE USE CASE

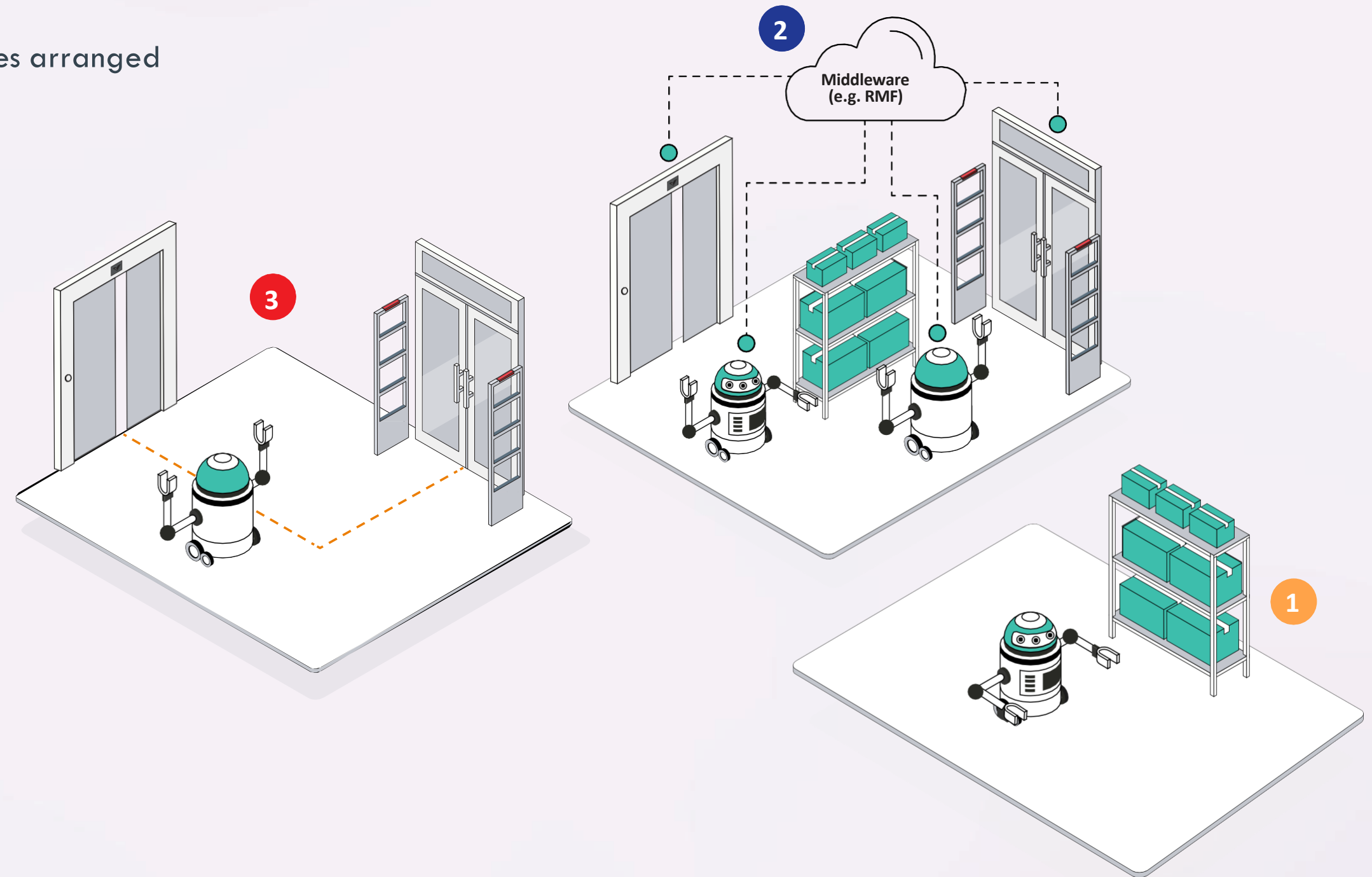
The AMR technical reference to guide the selection of your first use case.

Implementation approach

After identifying the sub-processes to automate and understanding the core AMR components, the next step is to determine the implementation approach.

When planning AMR implementation, consider these three approaches arranged by increasing complexity:

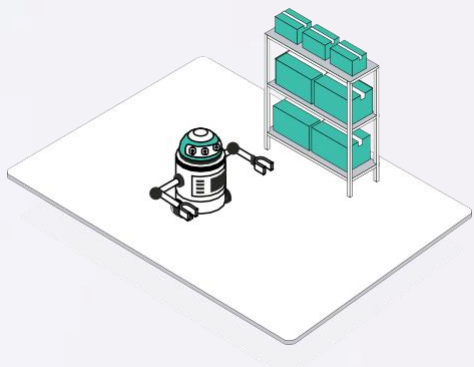
- 1 **Standalone robot** – Single robot, single use case with no integration to systems or infrastructure
- 2 **Single-robot to infrastructure** – One robot brand, integrated with infrastructure (e.g., lifts/doors)
- 3 **Multi-robot to infrastructure** – Multiple robot brands coordinated through middleware (e.g., RMF), in large facilities



3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

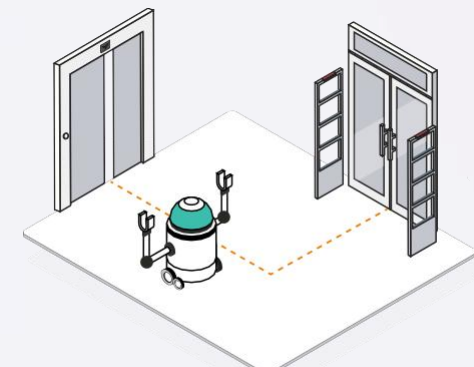
Comparison of the implementation approaches.



Standalone Robot

Single AMR operating autonomously within predefined zones, without integration into building infrastructure or external systems.

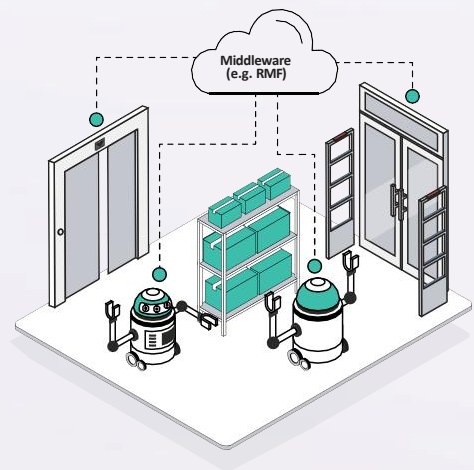
- ✓ **Operational adaptability:**
Robots can be relocated, re-mapped, or repurposed with minimal effort.
- ✓ **Faster deployment:**
Simplified integration with a single vendor stack.
- ✓ **Single-vendor support:**
One contract for maintenance, updates, and troubleshooting.
- ✗ **Limited automation depth:**
Robots unable to independently access lifts, doors, or restricted areas. Manual hand-offs required.
- ✗ **Vendor lock-in:**
Limited flexibility in switching vendors later.
- ✗ **Potential future rework:**
Transitioning to integrated deployment may require re-mapping or re-commissioning.



Single-Robot to Infrastructure

Single AMR integrated with building infrastructure to maximise operational efficiency.

- ✓ **Enhanced operational efficiency, higher throughput:**
Seamless workflow integration.
- ✓ **Comprehensive automation:**
Automation beyond individual robot capacity.
- ✓ **Faster deployment:**
Simplified integration with single vendor stack.
- ✗ **Potential future rework:**
Transitioning to integrated deployment may require re-mapping or re-commissioning.
- ✗ **Vendor lock-in:**
Limited flexibility in switching vendors later.
- ✗ **Integration challenges:**
Difficulty in adding robots from other vendors.



Multi-Robot to Infrastructure

Multiple AMRs from different vendors coordinated through middleware (e.g., RMF) to manage shared spaces and infrastructure.

- ✓ **Enhanced operational efficiency, higher throughput:**
Seamless workflow integration and automation beyond individual robot capacity.
- ✓ **Flexible and scalable:**
Heterogeneous robots from any vendor can be added at any time.
- ✓ **Minimal future rework:**
New robots require only minor adaptation with no vendor lock-in.
- ✗ **Longer deployment timelines:**
Complex integration across multiple systems.
- ✗ **Higher upfront costs:**
Middleware, integration, and infrastructure investment.
- ✗ **Specialised expertise required:**
RMF, systems integration, and operations.

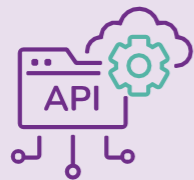
3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

Methods for integrating robot to infrastructure

Integrating robots with infrastructure enables seamless interaction, such as calling a lift and receiving its status. This applies only to Single-Robot to Infrastructure and Multi-Robot to Infrastructure implementations. The following outlines the common integration methods.

Single Robot to Infrastructure



Vendor Provided
Cloud-API Integration

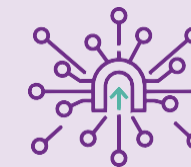


Control Panel
Modification



Dry Contact
Integration

Multi-Robot to Infrastructure



Gateway
Integration



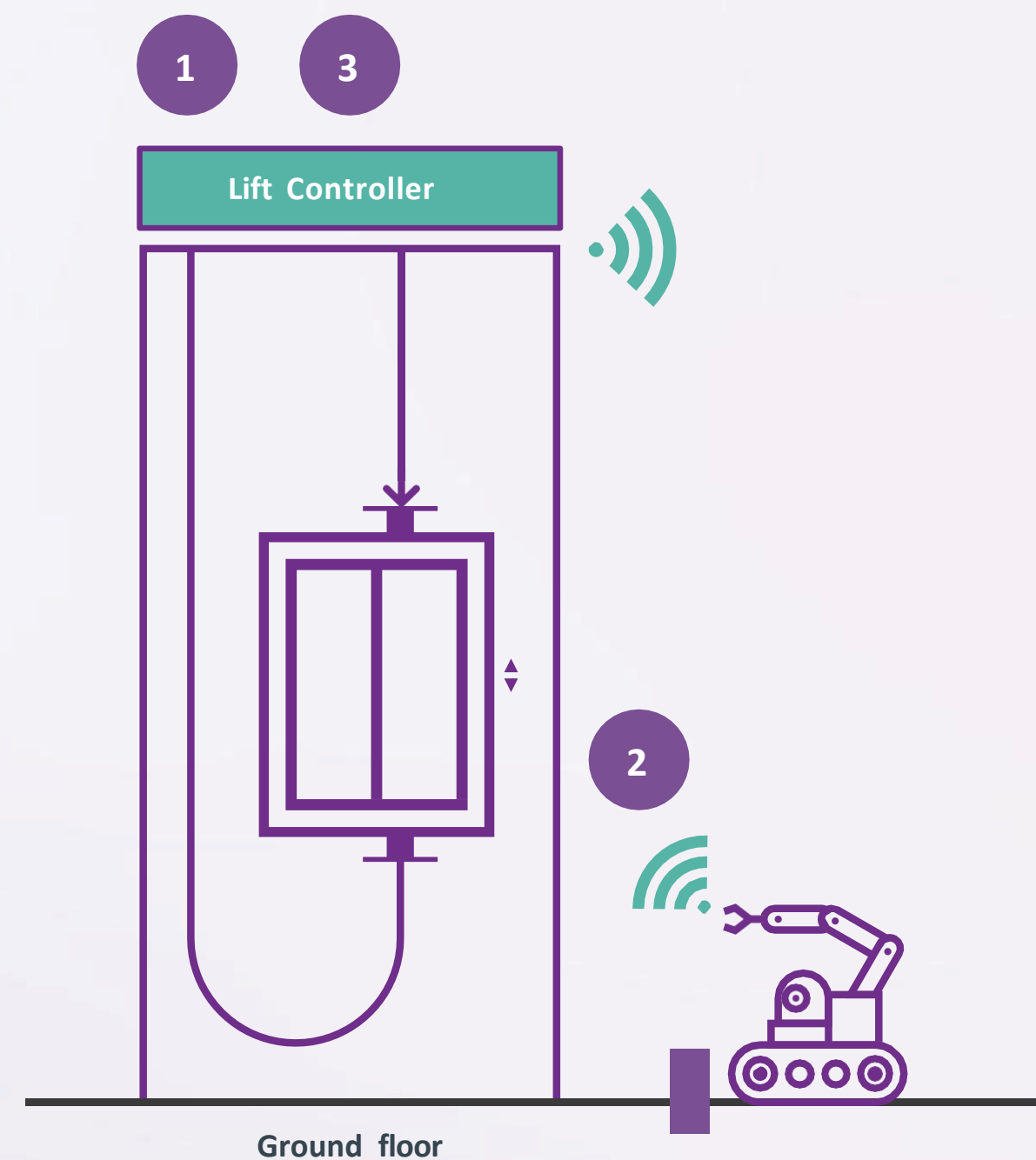
Sensor-based
Integration

3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

Single-robot to infrastructure

To integrate a robot with building infrastructure, the infrastructure must first be enabled to communicate with the robot. Several methods exist for establishing this robot-infrastructure integration.



Using robot-to-lift integration as an example, the illustration shows where the different integration methods are applied. The chosen integration method will influence the cost, effort, and time required for implementation.

- 1. Vendor-provided API Integration:** Some lift OEMs offer modern lifts with dedicated APIs, allowing third-party robots to call, dispatch, and ride elevators without physical contact. This enables direct software integration with the lift system — supporting functions such as lift calls, floor selection, and status monitoring.
- 2. Control Panel Modification:** Physical modification of the lift control panel to accept AMR inputs and send signals directly to the lift control circuits. This applies to legacy lift infrastructure that is not available with dedicated APIs.
- 3. Dry Contact Integration:** Electrical Integration that uses relay contacts to trigger lift operations through simulated button presses or basic control signals. Can be implemented at the lift controller, typically via dedicated relay input terminals.

**Physical robot-lift interaction, such as manipulator-based operation of lift controls, remains an active area of development and has not yet achieved reliable or widespread deployment*

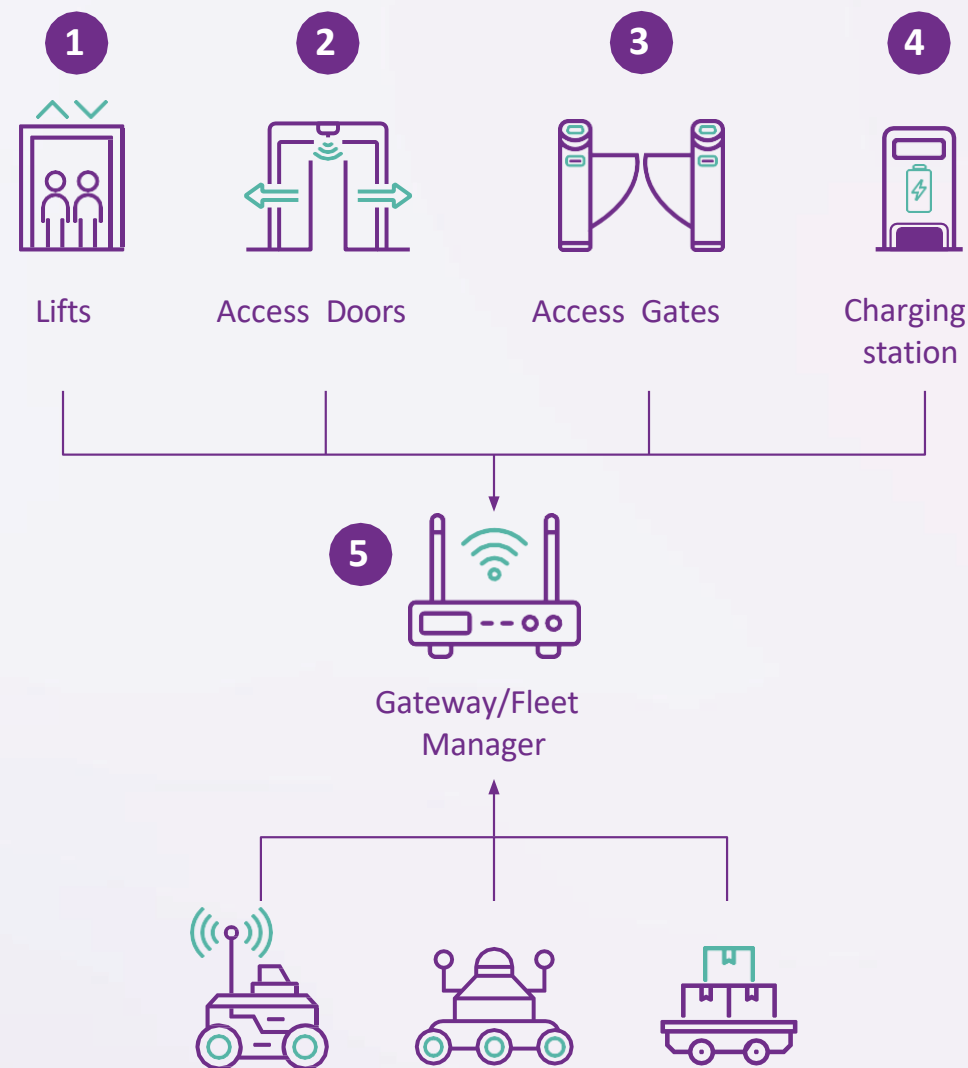
3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

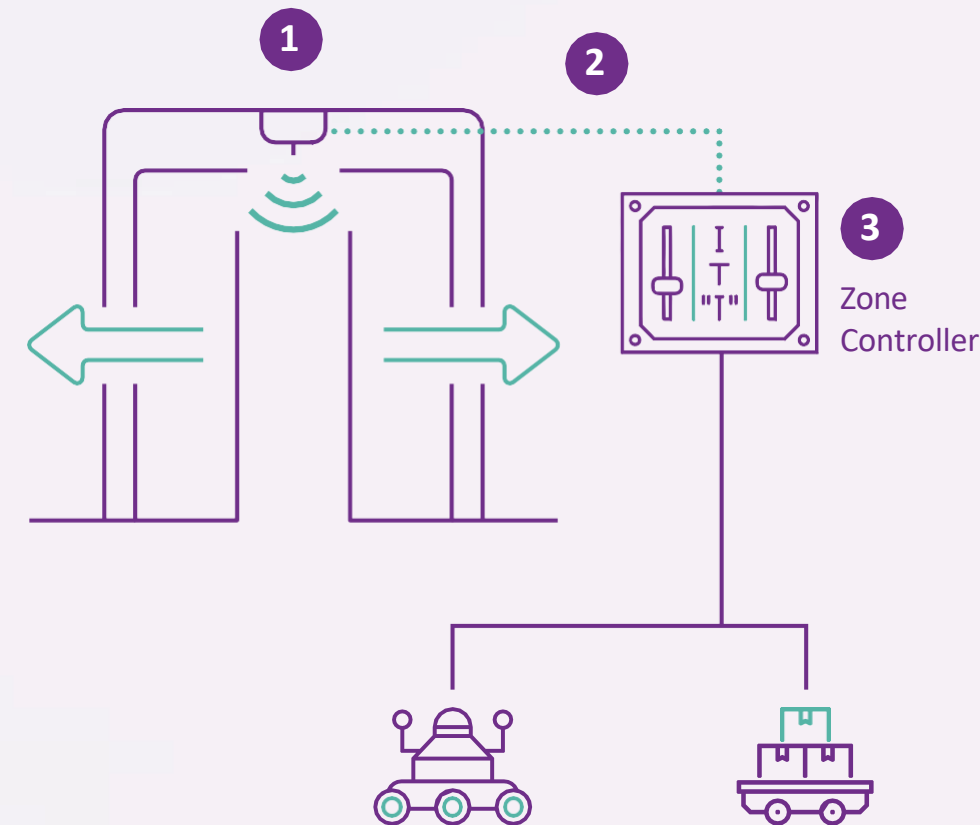
Multi-robot to infrastructure

Multiple AMR vendors can be deployed across large facilities, using middleware (such as RMF-based middleware) to coordinate shared infrastructure such as lifts, doors and corridors. Sitting above each vendor's fleet management system, the middleware resolves conflicts over shared resources without requiring robots to run on the same platform.

Gateway Integration



Sensor Based Integration



Unlike standalone deployments where robots operate independently, infrastructure-integrated systems require coordination protocols, shared control systems, and safety interlocks across multiple components.

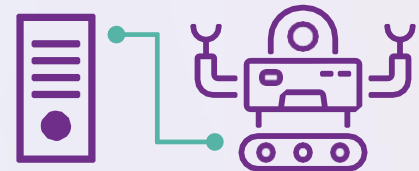
- **Gateway Integration:** Uses communication gateways (e.g., RMF-based middleware) or bridge devices to translate between different communication protocols, allowing robots and lifts using different control systems to communicate.
- **Sensor-Based Integration:** Uses external sensor networks such as RFID, infrared, or wireless communication systems to detect robot presence and automatically trigger lift operations without direct electrical connections.

3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

Beyond the three implementation approaches, Teleoperations, AI-Enablement or both can enhance AMR capabilities. As AMRs move beyond simple, self-contained tasks, Teleoperations enables remote human intervention, while AI-Enablement uses real-world data to help robots perceive, decide and respond more effectively

Teleoperations



Hardware Integration:

- To connect the operator console to the robot for live video feed and remote controls



Software Integration:

- For seamless monitoring of fleets, assigning of tasks and managing exceptions



Cloud Integration:

- Allows for extended monitoring and control of robots across sites

AI-Enablement



Sensor-Based Integration:

- To provide increased autonomy while providing the robot a richer view of its environment through improved perception and optimisation

Tele-operations provides a controlled human fallback; AI enablement reduces the frequency and effort of intervention over time.

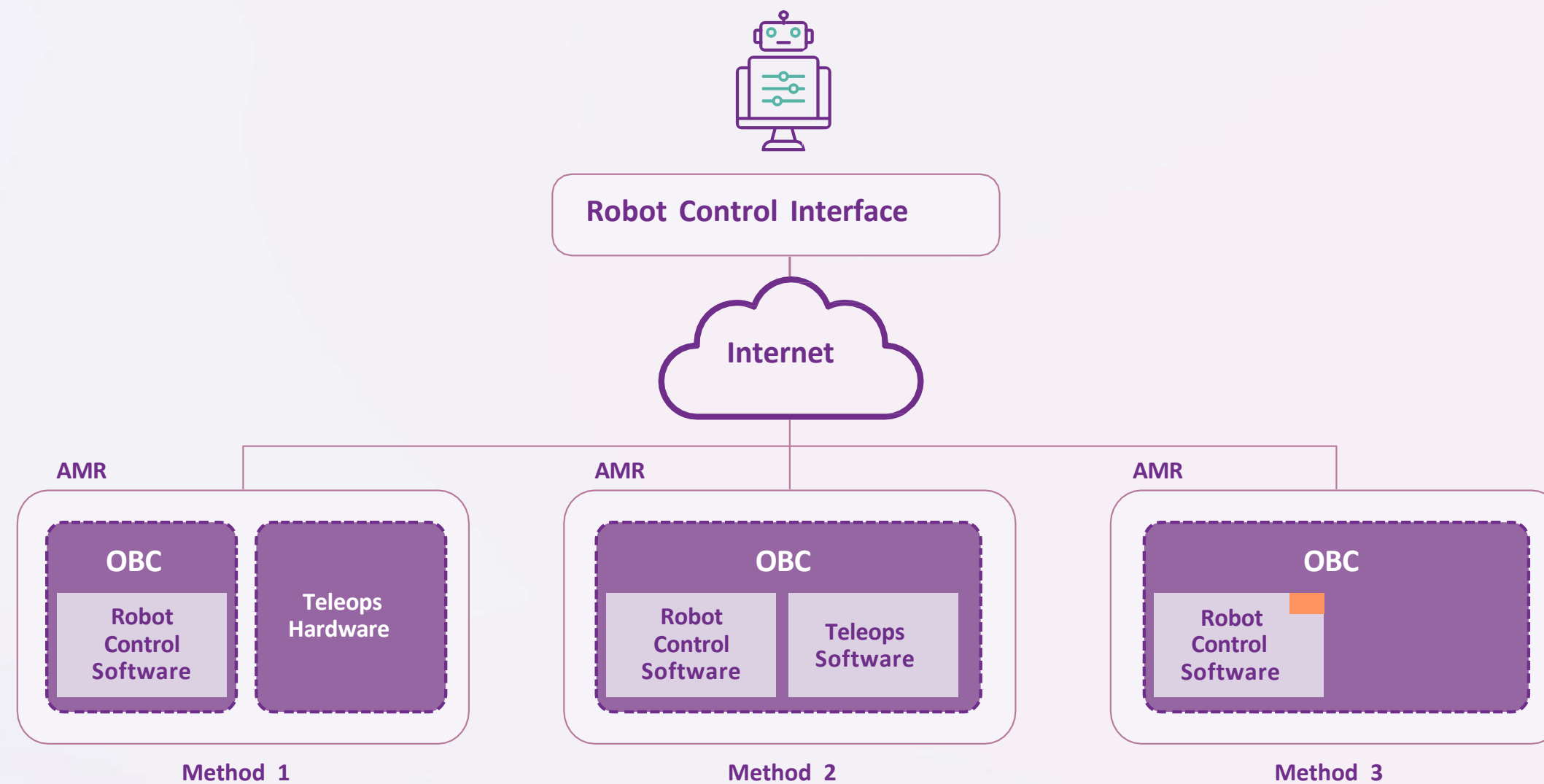


3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

Teleoperations

AMR teleoperation enables operators to remotely monitor and control robots using a remote control interface supported by live video feeds and sensor data transmitted over wireless networks. It is typically used when autonomous navigation requires human intervention, allowing operators to guide AMRs through complex situations while maintaining safe operations.



Method 1: Hardware Integration

Teleoperation software runs on dedicated external hardware connected to the AMR's onboard computer. Suitable when onboard compute resources are limited or software modification is restricted.

Method 2: Software Integration

Teleoperation software runs directly on the AMR's onboard computer, typically as containerised services (e.g., Docker). Enables tighter integration, lower latency, and greater flexibility.

Method 3: Cloud integration

The AMR communicates directly with cloud-based teleoperation services for monitoring and control. Supports scalable, centralised operations but depends on reliable low-latency connectivity.

3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

Teleoperations can provide a shared view of robot location, status, faults and intervention options. The right approach depends on vendor-permitted access, required functionality, the enterprise’s ownership and cybersecurity requirements, and the time and budget available for integration.

Decision factor	What to ask	Implication
Vendor openness	Will each vendor permit hardware changes, software installation or API access?	May rule out hardware or software integration in multi-vendor fleets.
Integration access	What APIs, SDKs, data streams and control functions are available?	Determines whether the dashboard can only monitor, or can also dispatch tasks and support intervention.
System ownership	Who owns the robot, onboard computer, fleet manager and collected data?	Defines who can approve changes, access data and maintain the integration.
Desired functionality	Do you need visibility only, alerts, task dispatch, remote assistance or direct control?	Higher-control functions require deeper access, safety validation and stronger controls.
Customisation and time	Is an off-the-shelf connector adequate, or is bespoke development required?	More customisation increases integration effort, testing time and delivery risk.
Cost and lifecycle support	What are the build, licence, connectivity, maintenance and upgrade costs?	Consider total cost of ownership, not just initial integration cost.
Cybersecurity and data	Where will video, telemetry and command data flow and be stored? Who can access it?	Requires agreed network controls, user roles, logging, retention and incident processes.

Note: In a multi-vendor environment, a shared teleoperations dashboard may not be feasible if robot providers restrict physical modifications or system and API access. A cloud or API layer can be less intrusive, but may require additional development, budget and time.

3 CHOOSING THE USE CASE

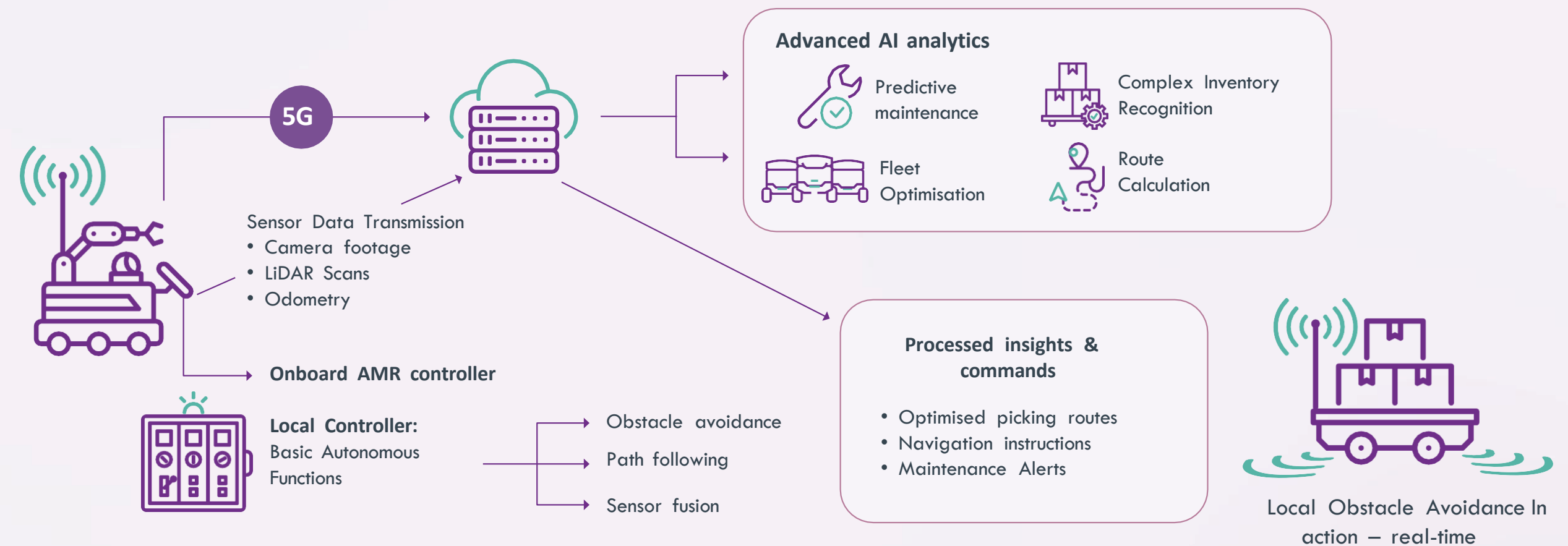
The AMR technical reference to guide the selection of your first use case.

AI-Enablement

AI-enablement allows AMRs to offload compute-intensive processing to cloud or edge servers for advanced analytics and decision-making. Sensor data is transmitted for analysis, while onboard controllers maintain basic autonomous functions and safe operation. Processed insights and commands are then returned to support tasks such as predictive maintenance, fleet optimisation, inventory recognition, and route planning.

Potential Use Cases

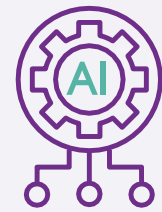
- Detecting space availability in lift
- Crowd detection with spatial breadth and depth to allow for navigation
- Heat map of frequently accessed inventory, path or area
- Smart scheduling based on human traffic data



3 CHOOSING THE USE CASE

The AMR technical reference to guide the selection of your first use case.

AI should be selected to solve a defined operational problem—not added as a feature. Match the required capability, available data and integration effort to a use case with a measurable outcome.



AI capability

Computer vision



Practical AMR use cases

Detect obstacles, blocked routes, people or unsafe conditions; identify lift-space availability



Operational value

Safer navigation and fewer avoidable stops

Spatial analytics

Produce congestion heat maps; analyse frequently used, underused or inaccessible areas

Better layout, routes and operating schedules

Predictive analytics

Identify abnormal battery, motor or sensor patterns; trigger maintenance alerts

Less unplanned downtime and improved availability

Optimisation algorithms

Dynamically assign tasks; adjust routes around congestion; prioritise urgent jobs

Improved throughput and robot utilisation

Recognition models

Recognise inventory, barcodes, loading bays or number plates where applicable

Reduced manual checking and more reliable handovers

Data fusion

Combine fleet, sensor, WMS/FMS and site data to identify recurring bottlenecks

Better operational decisions and continuous improvement

Ask vendors to specify the use case, data required, decision owner and measurable operational benefit and not only the AI capability.

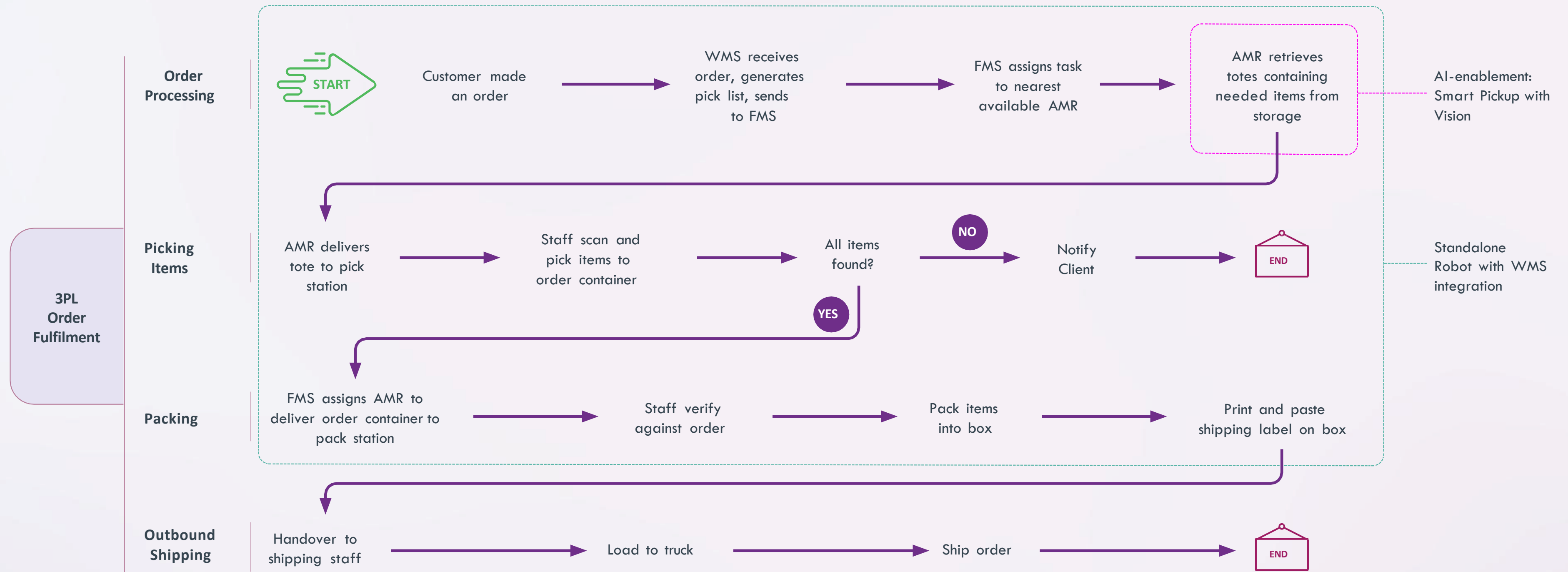
**AI-enabled recommendations should be validated against site rules, safety procedures and human oversight requirements before they are used to change AMR operations.*

3 CHOOSING THE USE CASE

Designing the to-be process with AMR

The to-be process helps identify where AMRs can be integrated into existing workflows and serves as a baseline for vendor discussions.

Below is an example of the 3PL order fulfilment use case, with AMR-enabled process steps shown in green.



DEVISE HIGH-LEVEL TIMELINE & PLAN

Besides site preparation, vendor discussions, and business case approval, most AMRs projects also require process redesign, system integration, acceptance testing, training, safety validation, pilot management, and post-go-live stabilisation.

This critical section provides a clear timeline of key activities, helping coordinate stakeholders, avoid common deployment pitfalls, and set realistic expectations.

[Company/Project Name] – AMR Implementation Roadmap
Project Start Date: [DD/MM/YYYY] | Target Go-Live Date: [DD/MM/YYYY]

Phase	Estimated Timeline	Project Manager Milestones & Checkpoints	Owner / Status
Phase 1: Internal Planning & Readiness	Month_____ to_____	☐ Visualise your current operations. ☐ Complete facility layout mapping and site audits. ☐ Define target use cases and baseline KPIs.	Owner: _____ STATUS: []
Phase 2.1: Vendor engagement & solution design	Month_____ to_____	☐ Issue RFP, evaluate bids, and select AMR partner. Co- ☐ design target day-to-day robot workflows. ☐ Draft initial SOP and training frameworks.	Owner: _____ STATUS: []
Phase 2.2: Vendor build & site preparation	Month_____ to_____	☐ Issue RFP, evaluate bids, and select AMR partner. Co- ☐ design target day-to-day robot workflows. ☐ Draft initial SOP and training frameworks.	Owner: _____ STATUS: []
Phase 3: Trial, acceptance & go-live	Month_____ to_____	☐ On-site delivery, mapping, and localization. Execute ☐ User Acceptance Testing (UAT) sign-off. Conduct ☐ champion user and operator training. ☐ Run operational trials and track system performance.	Owner: _____ STATUS: []

5

SITE AND INFRASTRUCTURE PREPARATION

Assess and prepare your facility's physical layout, network, power, and safety systems before AMR deployment. This helps prevent delays, reduce rework, and provide vendors with the information needed for accurate proposals.

Key Preparation Areas



Physical Environment:

Measure aisles, doors, ramps, and floor conditions. Check for cracks, debris, and traffic zones. Mark potential AMR routes with temporary tape.



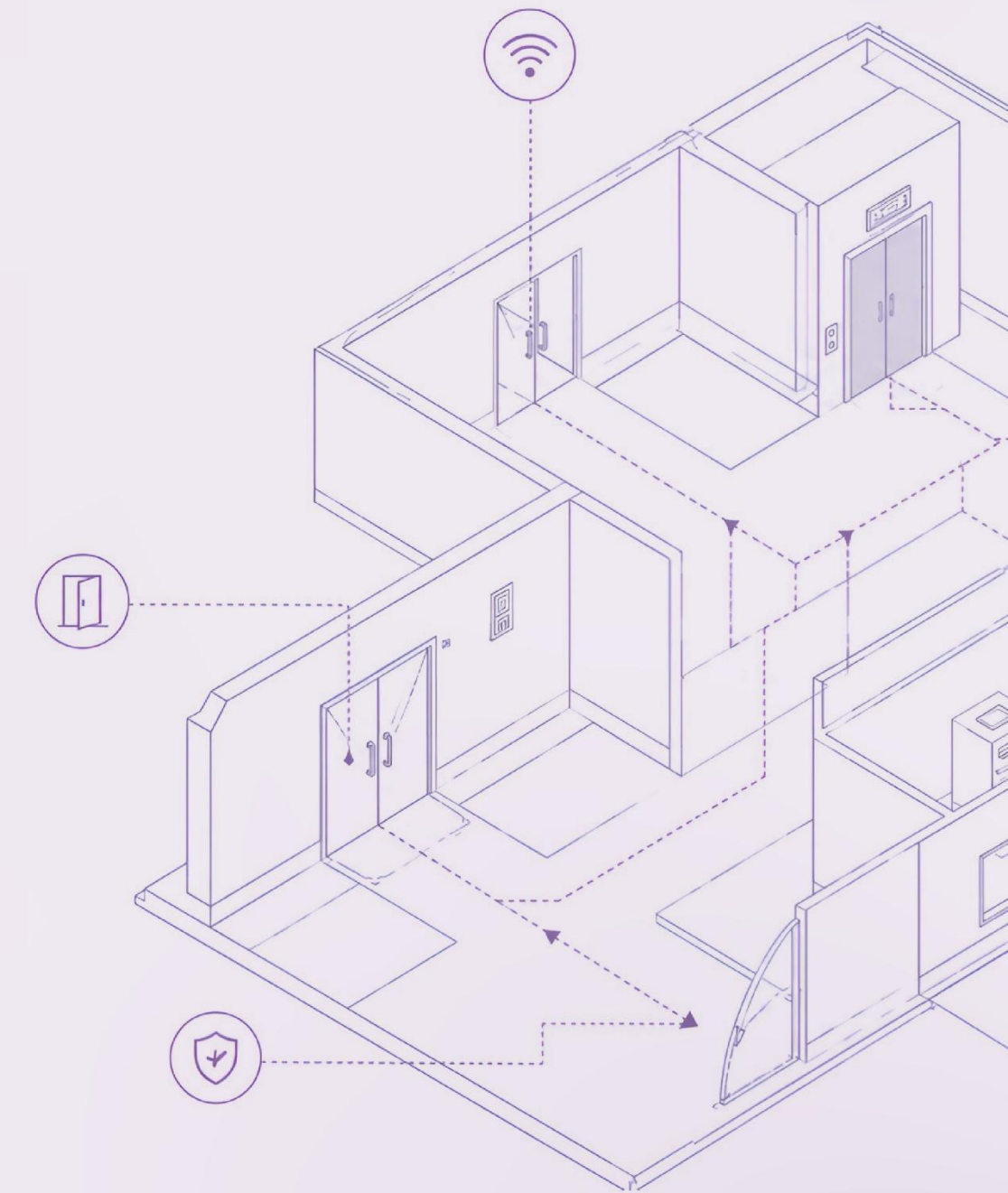
Infrastructure & Connectivity:

Identify charging station locations with nearby 220V outlets and stable power supply. Test network coverage along planned routes and install additional access points where needed.



Safety & Compliance:

Install signage and barriers at blind spots. Define loading and unloading zones, and brief staff on operational rules.



Use the checklist on the following page to support preparation, vendor discussions, and compliance reviews against relevant standards.

1. Physical Environment Readiness

To minimise mechanical friction and ensure the robot can navigate without getting stuck or damaged.

Floor Condition Assessment

- ☐ Large cracks and potholes
- ☐ Steep inclines exceeding robot gradeability limits Areas requiring repair

Debris and Obstruction Survey

- ☐ Loose items (e.g., zip ties, plastic wrap, sawdust)
- ☐ Potential wheel, tread, or cable guard entanglement risks
- ☐ Obstructions along planned routes

- Aisle Width and Clearance Verification** Clearance at
- ☐ pinch points and high-traffic areas Vertical clearance
 - ☐ along with planned routes Areas requiring width or height adjustments

Environmental Conditions Assessment

- ☐ Lighting conditions for sensors
- ☐ Reflective surfaces affecting optical or laser navigation
- ☐ Exposure to rain and high-temperature zones

Threshold Compatibility Review

- ☐ Door thresholds exceeding step-climbing capability Ramps required along planned routes
- ☐ Ramp specifications meeting operational requirements

2. Infrastructure & Connectivity

A robot is only as effective as its connection to the brain, the server.

Network Coverage Assessment

- ☐ Wi-Fi/5G coverage along planned AMR routes
- ☐ Dead zones and weak signal areas
- ☐ Signal quality at operating heights

Signal Interference Evaluation

- ☐ High-interference areas (e.g., heavy shelving, machinery)
- ☐ Additional access points or signal boosters required Stability of industrial router connections

Power Infrastructure Review

- ☐ Suitable charging station locations
- ☐ Nearby power outlets and electrical capacity
- ☐ Charging station accessibility

System Integration Compatibility

- ☐ Network or cloud gateway support for robot communications
- ☐ Compatibility with existing systems (e.g., WMS)
- ☐ Network protocols and security systems

Data Readiness Assessment

- ☐ Availability of required operational data
- ☐ Data sources (e.g., facility maps, inventory, workflows) Real-time updates and data accuracy

3. Safety & Compliance

Ensure humans and robots can coexist without incidents.

Visual Safety Indicators

- ☐ Wi-Fi/5G coverage along planned AMR routes
- ☐ Dead zones and weak signal areas
- ☐ Signal quality at operating heights

Traffic Management Protocols

- ☐ Traffic flow rules and lane designations
- ☐ Human-robot interaction points and intersections Safety controls and signage in high-traffic areas

High Traffic Area Assessment

- ☐ Peak traffic periods and crowd density
- ☐ Additional safety measures or alternative routing required
- ☐ Alignment of robot detection capabilities with pedestrian traffic

Meeting Regulatory Requirements

- ☐ Compliance with appliance safety regulations Required documentation, certifications, and approvals Operational requirements verified before deployment

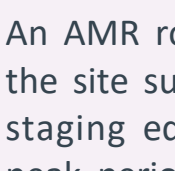
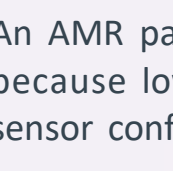
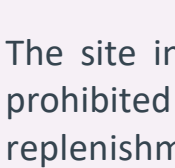
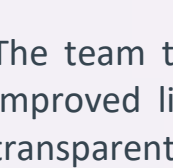
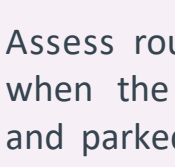
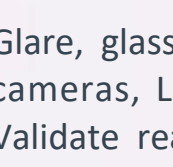
5

SITE AND INFRASTRUCTURE PREPARATION

Why site and infrastructure preparation matters

Checklists are a useful starting point, but site readiness goes beyond ticking boxes. Real-world AMR deployments often encounter conditions such as floor surfaces, lift dimensions and mixed fleet operations that affect robot performance and operational continuity. The following scenarios complement the checklist by helping teams identify and address these issues before deployment.

Physical Route Constraints

	1. Lift threshold and wheel clearance	2. Aisle clearance reduced during operations	3. Lighting and reflections disrupted navigation
Scenario	 An AMR entered the lift but repeatedly stalled at the cabin threshold because its wheels could not cross the gap reliably.	 An AMR route met clearance requirements during the site survey, but temporary pallets and staging equipment narrowed the aisle during peak periods.	 An AMR paused near a glass entrance after dark because low light, glare and reflections affected sensor confidence.
Resolution	 The team tested the full lift route and selected a robot with a suitable wheel configuration.	 The site introduced marked robot lanes, prohibited staging zones and revised replenishment procedures.	 The team tested the route at different times, improved lighting and added visual treatment near transparent surfaces.
Why it matters?	 A robot that fits inside a lift may still be unable to use it reliably. Assess thresholds, gaps and ground clearance early	 Assess routes during normal operations, not only when the floor is clear. Include people, pallets and parked equipment.	 Glare, glass and reflective floors can affect cameras, LiDAR and optical navigation. Validate real operating conditions.

5

SITE AND INFRASTRUCTURE PREPARATION

Connectivity and operating environment

General building coverage is not the same as operational readiness. Test conditions where AMRs travel, charge, hand over between networks and recover from exceptions.

		4. Coverage passed, roaming failed	5. Charging dock created a bottleneck	6. Local conditions degraded performance
Scenario		The building Wi-Fi map showed coverage, but the AMR lost commands at the lift lobby and sheltered link during network handovers.	A charging dock near dispatch became congested during busy periods, creating a trip hazard around the charging area.	An AMR slowed near dense shelving and machinery where debris, signal interference and local environmental conditions affected performance.
Resolution		The team tested roaming, latency and dropouts along the route, then adjusted access points and introduced cellular fallback.	The team relocated the dock to a protected location with adequate power, clear approach space and traffic rules.	The team cleaned and protected the route, reviewed local conditions with the vendor and adjusted the AMR path.
Why it matters?		Test connectivity while the robot moves, especially at transition zones. Distinguish control, telemetry and video requirements.	Charging is an operational asset, not just a power outlet. Plan access, capacity, safety and battery-related workflows.	Check route-specific debris, metal structures, machinery and environmental conditions, not only dimensions and Wi-Fi coverage.

5

SITE AND INFRASTRUCTURE PREPARATION

Connectivity and operating environment

General building coverage is not the same as operational readiness. Test conditions where AMRs travel, charge, hand over between networks and recover from exceptions.

		7. Outdoor route crossed a public path	8. Shared intersection caused delays	6. Poor coverage feedback lacked location context
Scenario		A planned outdoor AMR route crossed from managed premises onto a public path. The team assumed robot speed was the only constraint.	During shift changes, AMRs, pedestrians and forklifts converged at a shared intersection, causing repeated stops and unsafe workarounds.	The enterprise told its vendor that several locations had poor connectivity but could not identify the route segment, root cause or affected function.
Resolution		The team mapped each route segment, engaged LTA early and adjusted the trial design around the approved operating conditions.	The site introduced lane markings, right-of-way rules, peak-period routes and an escalation process for blocked paths.	The team shared a marked route plan, weak-zone observations and the impact on robot control, telemetry and diagnostics.
Why it matters?		Public-path operation requires the appropriate approval. Plan for route, operating hours, supervision and safety conditions, not just speed.	Sensors alone do not manage mixed traffic. Define shared-space rules, peak-period procedures and human response procedures before go-live.	Specific location and data findings help vendors recommend practical network improvements, route changes or cellular fallback.



VENDOR ENGAGEMENT & SOLUTION DESIGN

To ensure initial discussions are productive and aligned with business needs, treat the next steps as a vendor briefing package. Use them to define how the solution should operate, how users will be trained, how acceptance will be tested, and how performance will be tracked before go-live.



6 ENGAGING THE VENDORS

This phase transitions the AMR from planning into live operations. The focus is on validating performance through structured trials, confirming readiness against acceptance criteria, and ensuring the solution is operationally ready for go-live.

During vendor engagement, discuss the following:

- Validate the problem statement and use case
- Conduct a site assessment
- Conduct a on-site or off-site demo or trial
- Review operational workflows
- Align on SOPs and training requirements

Request the following from prospective vendors:

- Proposal covering scope, deliverables, milestones, testing approach, timeline, and support
- Detailed cost breakdown
- Relevant project references and case studies
- Safety, quality, and compliance records

6 ENGAGING THE VENDORS

Evaluate vendor capabilities, solution fit, and total cost to support vendor selection and procurement decisions.

1



CLARIFY YOUR DECISION CRITERIA

Functional fit

Ability to support the required workflows, payloads, environments, and integrations

Ease of use for your team

User interface, configuration, and troubleshooting requirements

Implementation approach

Testing approach, support model, response times, and training

Total cost (3–5 years)

Hardware, software, support, and recurring costs

Local presence and track record

Relevant experience and customer references

Integration capabilities

Support for WMS/ERP, APIs, scanners, and other systems

Knowledge transfer

Training, documentation, and operational handover

Stakeholder involvement

Engage relevant business and operational stakeholders

2

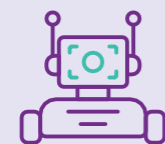


VALIDATE WITH CONCRETE SCENARIOS

Use 2–3 realistic scenarios and ask vendors to demonstrate:



How missions are triggered and monitored



How the robot navigates operational environments



How exceptions are handled (e.g., blocked paths, low battery, connectivity issues)

3



COMPARE TOTAL COST & RISK

Consider total cost over 3–5 years:



One-time costs

Robots, chargers, infrastructure, integration, and deployment.



Recurring costs

Software licences, support, connectivity, and managed services.



Optional costs

Training refreshers, spare parts, expansion, and additional robots.

7

DESIGNING HOW AMRs WORK DAY-TO-DAY

This section covers the design of AMR-enabled workflows, including how robots interact with people, processes, and infrastructure. Planning should begin during vendor engagement to align operational requirements and identify potential challenges early.

Below are key areas project managers can explore with vendors when designing day-to-day AMR operations.

01



Task Management

Who decides which robot does what, and in what order?

- Define task priorities and sequences
- Establish task assignment rules
- Design workflows for routine operations
- Define handoff procedures between humans and robots

02



Human-Robot Interaction

How do people and robots work together?

- Define interaction protocols
- Establish communication methods and signals
- Create clear handoff procedures
- Design collaborative workflows

03



Operational Scheduling

When should robots operate, recharge, and undergo maintenance?

- Plan charging schedules and battery management
- Design maintenance windows and service protocols
- Define operational hours and shift patterns
- Establish downtime management procedures

7

DESIGNING HOW AMRs WORK DAY-TO-DAY

This template helps project managers document the redesigned workflows. Define a scenario and redesigned process for each category below.

Task Management

Scenario:

AMR → Human Handoff: How does the robot signal to the human that it is ready?

Redesigned process:

- Robot arrives at picking station
- Indicator light signals arrival
- Picker loads items into tote on robot
- Picker confirms completion and releases robot

Human-Robot Interaction

Scenario:

Robot → Human Signals: How does the robot make its status obvious?

Redesigned process:

- Lights and sounds show robot status
- On-robot screens provide user prompts
- Robots slow and chime near people
- Maintenance messages provide clear instructions

Operational Scheduling

Scenario:

Scheduling: How to match robot tasks with daily operations?

Redesigned process:

- Historical data identifies peak and off-peak periods
- Replenishment is scheduled during quieter periods
- Time-window rules restrict robot operations where needed
- High-priority tasks can override routine jobs

8

SOP & TRAINING

Standard Operating Procedure (SOP)

SOPs define how routine tasks, exceptions, and emergencies should be handled to ensure safe and consistent operations. They support training, clarify responsibilities, and standardise execution across teams.

Project managers should involve vendors in designing or reviewing SOPs. The examples below show how exception scenarios can be addressed.

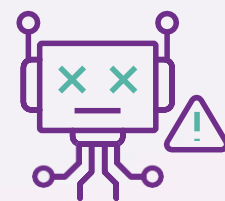


Exception Scenario 1: Item not in bin (inventory error)

Robot goes to bin L5-R3 to pick item ABC123. The item is not present.

Standard Operating Procedures

- Robot reports item not found to WMS and supervisor
- Task pauses pending investigation
- Supervisor verifies whether item is missing or misplaced
- If missing: Mark item as out-of-stock and reassign remaining items
- If misplaced: Update WMS and resume robot task
- Investigate root cause and recount the bin



Exception Scenario 2: Robot gets stuck en route

Robot reports a blocked path.

Standard Operating Procedures

- Supervisor receives an alert on the dashboard
- Supervisor whether path is physically blocked
- If blocked: Clear the obstacle and resume robot operation
- If not blocked: Robot attempts self-recovery for 2 minutes
- If recovery fails: Take robot offline and reassign task to backup robot
- Investigate root cause and review localisation accuracy



Exception Scenario 3: Picker not at station when robot arrives

Robot arrives at picking station #02 with items, but the picker unavailable.

Standard Operating Procedures

- Robot waits at station a defined period (e.g., 5 minutes)
- If picker returns: Handoff proceeds normally
- If picker does not return: AMR reports picker absent
- Supervisor redirects robot to a different station or pauses the task
- Picker receives an absence notification

8

SOP & TRAINING

Building on well-designed SOPs, training helps staff adapt to AMR-enabled workflows and operate safely and confidently in robot-integrated environments.

When preparing end-users to operate AMRs, design training around people, process, and safety—not just buttons and screens. These three categories below highlight key areas to consider when working with vendors to develop training programmes.

Safety & Risk Awareness

- Explain AMR safety features and emergency procedures (e.g., sensors, speed limits, E-stop, escalation process)
- Walk staff through blind spots, shared aisles, and no-go zones, and explain relevant risk controls aligned with ISO 3691-4

Role Clarity & Responsibilities

- Define responsibilities for robots and staff, including routine tasks, quality checks, and exception handling
- Clarify ownership of handoffs, escalations, and operational decisions

Human–Robot Interaction & Mindset

- Teach interaction rules, including right-of-way practices and robot status indicators
- Explain how AMRs reduce physical strain and support higher-value work to build trust and adoption



TRIAL, ACCEPTANCE & GO-LIVE

This phase transitions the AMR from planning into live operations. The focus is on validating performance through structured trials, confirming readiness against acceptance criteria, and ensuring the solution is operationally ready for go-live.



9 USER ACCEPTANCE TEST

User Acceptance Testing (UAT) is a critical step before the operational trial, validating that the solution performs as expected in the actual operating environment. Without UAT, issues may only surface during the operational trial, when they are more costly and disruptive to address.

UAT confirms three things:

A. Technical readiness

Robot performs required tasks in the actual environment

B. Process readiness

Workflows, handoffs, and exception handling function as designed

C. People readiness

Teams can operate the system confidently and safely

What Happens After UAT?

UAT findings feed directly into the operational trial:

- **Refined SOPs:** UAT feedback improves exception handling procedures
- **Training updates:** UAT findings inform additional training before trial
- **System tuning:** UAT issues drive vendor configuration changes
- **Success metrics baseline:** UAT establishes baseline performance for trial comparison

UAT is the stage where end-users validate that they can perform their jobs safely and effectively alongside the robot.

9 USER ACCEPTANCE TEST

User Acceptance Testing (UAT) validates that the solution works as intended, while the **operational trial** validates performance under real operating conditions. The key differences are summarised below.

Aspect	User Acceptance Test (UAT)	Operational Trial or Pilot Deployment
Focus	• End-users validate that the solution meets operational requirements • Tests defined scenarios in a controlled environment	• Validates operational performance under real operating conditions • Tests sustained operations under actual workloads
Why It's Important	Identifies issues before deployment and operational trial	Demonstrates operational performance and business value before full-scale deployment
Duration	Typically 1–3 days of structured testing	Typically 1–4 weeks of live operations
Who Runs It	Project manager, vendor, and end-users	Operations team within normal workflows
Examples	AMR completes 50 pick-to-pack cycles	AMR handles 500 real 3PL orders per day for one week

9

USER ACCEPTANCE TEST

UAT criteria can be either **Vendor-Defined** or **User-Defined**. The table below compares the strengths and limitations of each approach.

	Vendor-Defined UAT Criteria	User-Defined UAT Criteria
Definition	Test cases are defined by the vendor based on functional requirements	Success criteria are defined by business owners and end-users based on operational workflows
Pros	Technical rigor: Standardised test cases aligned with technical requirements Efficiency: Faster development of test scripts and acceptance criteria Clarity of scope: Focuses on contractually defined requirements	Operational relevance: Reflects actual workflows and business needs Higher adoption rates: Builds ownership and confidence among end-users Uncovering blind spots: Identifies workflow gaps and edge cases
Cons	Vendor-defined perspective: May overlook known limitations or edge cases Limited operational context: May not fully reflect day-to-day operations Misaligned success criteria: A system may pass vendor-defined UAT but still fall short of operational needs	Resource intensive: Requires significant time and participation from end-users Technical gaps: May include impractical tests due to limited technical knowledge Less measurable criteria: Success criteria may be harder to assess consistently

Use clear, measurable UAT criteria and ensure demonstrations are not substitutes for real user acceptance testing.

9 USER ACCEPTANCE TEST

Regardless of whether UAT criteria are Vendor-Defined or User-Defined, project managers should involve actual operational staff.

UAT should reflect real workflows, operating conditions, and user interactions to ensure meaningful feedback and readiness for deployment.



Selection & Capacity Planning

Select testers who reflect actual operational roles and day-to-day usage, not just availability.

- **The power user mix:** Include both tech-savvy and less tech-savvy operators
- **Backfill strategy:** Avoid overloading UAT staff by reducing normal workload to prevent rushed or incomplete reporting
- **Shift representation:** Include testers across different shifts to account for varying lighting and floor conditions

Standardise Reporting Tools

Unstructured feedback is difficult to investigate. Provide a consistent way to report issues that captures:

- **Timestamp:** Critical for reviewing robot logs
- **Location:** Where the issue occurred
- **Context:** What was happening (e.g., forklift crossing, wet floor)
- **Photo/video:** Capture the error code on the Human–Machine Interface (HMI) screen where possible



Feedback Loops & Psychological Safety UAT is intended to uncover issues. Testers should feel comfortable reporting problems and unexpected behaviour.

- **Daily de-briefs:** 15 minutes per shift to discuss issues and observations
- **Gamification:** Consider incentivising useful bug reporting
- **Direct access to tech:** Where possible, the vendor's engineers should be present during staff UAT to observe real-time issues

10

OPERATIONAL TRIAL & PERFORMANCE TRACKING

Define success criteria before testing begins. **Technical Acceptance Criteria** assess whether the robot completes tasks reliably without manual intervention. **Workflow Acceptance Criteria** assess whether tasks and exception handling follow defined SOPs with clear, actionable alerts. **User Acceptance Criteria** assess whether staff can complete tasks confidently and operate safely around robots.

Normal Path Scenario

- **Complete a full picking cycle:**
WMS assigns task → robot retrieves item → picker loads item → robot delivers to packing
- **Run a full cleaning cycle:**
Robot cleans designated area → docks for refill → resumes route → returns to charging
- **Execute a scheduled material delivery:** MES triggers task → robot retrieves materials → delivers to the assembly line

Exception Scenarios (To Test SOP)

- **Blocked path:**
Robot encounters obstacle → supervisor alerted → path cleared → robot resumes
- **Missing inventory:**
Robot reports item not found → picker follows SOP → task reassigned if required
- **Localisation lost:**
Robot stops → technician alerted → technician intervenes → robot resets
- **Operator absent:**
Robot arrives at station → no supervisor present → timeout triggers task reassignment

Edge Cases (To Stress Test)

- **Multi-robot convergence:**
Do multiple robots coordinate safely when they converge at the same point (e.g., lift door)?
- **Peak-hour congestion:**
During high-traffic periods, do robots yield appropriately and maintain flow?
- **Shift handover:**
During shift changes, does the incoming shift understand robot status and ongoing tasks?

10

OPERATIONAL TRIAL & PERFORMANCE TRACKING

Framing the Operational Trial

Define the operational trial scope by identifying the **objectives, success criteria, stakeholder responsibilities, and timelines** before deployment. This helps ensure a structured evaluation under real operating conditions and provides a clear basis for assessing performance.

LEARNING OBJECTIVES

What should be learned?

STEP 1

Define clear trial objectives

Focus on learning, validating assumptions, and gathering feedback before scaling. The trial should:

- Observe how the solution performs in a real environment
- Gather qualitative feedback from users and stakeholders
- Validate assumptions about operational value and performance
- Identify areas for improvement before wider deployment

TRIAL SCOPE

What will be tested?

STEP 2

Define detailed trial scope

Define the what, where, when, and how of the trial

A. Select the use case and key functions

Identify the primary use case for the pilot (e.g., last-mile delivery, guest wayfinding, cleaning)
Identify the key functions to test that the AMR must perform successfully

- **Logistics:** Navigate narrow corridors, operate automatic doors, and dock accurately at charging stations
- **Public spaces:** Detect obstacles in crowds, respond accurately to voice commands, and navigate to predefined points

- **Physical environment:** Specify where the pilot will take place
- **Operational zone:** Define the designated pilot area (e.g., lobby and first-floor corridor)

B. Delineate pilot features (baseline vs. stress-test) Define which features will be tested under normal and stress conditions

- **Baseline features:** Core functions used throughout the trial (e.g., navigation, safety sensors)
- **Stress-test features:** Advanced functions tested under specific conditions (e.g., peak-hour operations)

10

OPERATIONAL TRIAL & PERFORMANCE TRACKING

Framing the Operational Trial

PERFORMANCE INDICATORS

What data validates AMR performance and value?

STEP 3

Establish measurable performance indicators

A. Technical validation criteria

How will technical performance be measured?

- **Navigation reliability:** Percentage of missions completed without critical failure or manual intervention
- **Obstacle avoidance:** Number of obstacles detected and successfully navigated
- **Integration performance:** Number of successful lift and door integrations

B. Operational validation criteria

How will operational impact be measured?

- **Manual workload:** Reduction in staff-hours required
- **Exception rate:** Frequency of staff intervention, with root causes identified
- **Task completion:** Average time to complete each task

C. User acceptance & feedback

- **Staff feedback:** Gather feedback through surveys or logbooks
- **Customer and guest feedback:** Observational notes on interactions where applicable

10

OPERATIONAL TRIAL & PERFORMANCE TRACKING

Curating the Operational Trial

Successful trials require clear plans for training, support, and communication. Establish roles, escalation procedures, and support coverage early to ensure smooth operations throughout the trial.



Plan the trial execution, training, and support through a detailed operational plan.

A. CREATE A TRAINING & HANDOVER PLAN

Phase 1: Training & setup (e.g., 2 weeks) Provider-led training, staff familiarisation, route mapping, and initial testing.

- Covers robot operation, basic troubleshooting, safety protocols, and fleet management software

Phase 2: Core Functionality Trial (e.g., 4 weeks)

Continuous operation of baseline features and testing of key functions under normal conditions.

Phase 3: Stress Testing (e.g., 2 weeks)

Test advanced or operate the robot during peak periods to evaluate performance under load.

- Collect immediate staff feedback and refine the solution before full trial begins

B. FORMAL HANDOVER



Conduct a formal handover at the end of the training period



Establish a clear SLA from the TSP for emergency support during the pilot



Define the support request and escalation process during the trial

C. FINALISE THE DATA COLLECTION PLAN



Identify the data required to evaluate trial performance



Define how data will be collected and reported throughout the trial



Ensure the data supports performance review and go-live decisions

10

OPERATIONAL TRIAL & PERFORMANCE TRACKING

Post-trial performance tracking compares trial results against predefined targets to validate readiness for go-live. It confirms whether the AMR performs as expected, identifies issues early, and support deployment decisions with measurable results.



KEY METRICS REVIEW

Track trial performance using a simple spreadsheet. An example is shown below. In addition to these examples, track the success metrics agreed with stakeholders and leadership.

METRIC	TRIAL TARGET	WHAT IT REVEALS
Mission Success Rate	>95%	Route and navigation reliability
Uptime	>90%	System stability in real conditions
...	...	...



SIMPLE REVIEW PROCESS



Collect Data

Log metrics daily during the trial



Analyse

Conduct regular team reviews to highlight success, identify issues, and assess performance against KPIs.



Document

Record key findings, supporting evidence, and a go or no-go recommendation.



Act

Assign owners for fixes, re-test if needed, then transition to daily operations.

11

GO-LIVE

Go-live marks the transition from operational trial to full production use of the AMR, where it supports regular operations within the defined scope with minimal supervision. A successful go-live validates the benefits demonstrated during the trial and ensures a smooth transition into day-to-day operations. It shifts the focus from project implementation to business-as-usual, providing measurable business outcomes and a foundation for future scaling.

Following go-live, consider the following steps:

- Optimise existing AMR operations
- Scale deployments by adding more AMRs
- Expand to new use cases
- Continue tracking performance metrics

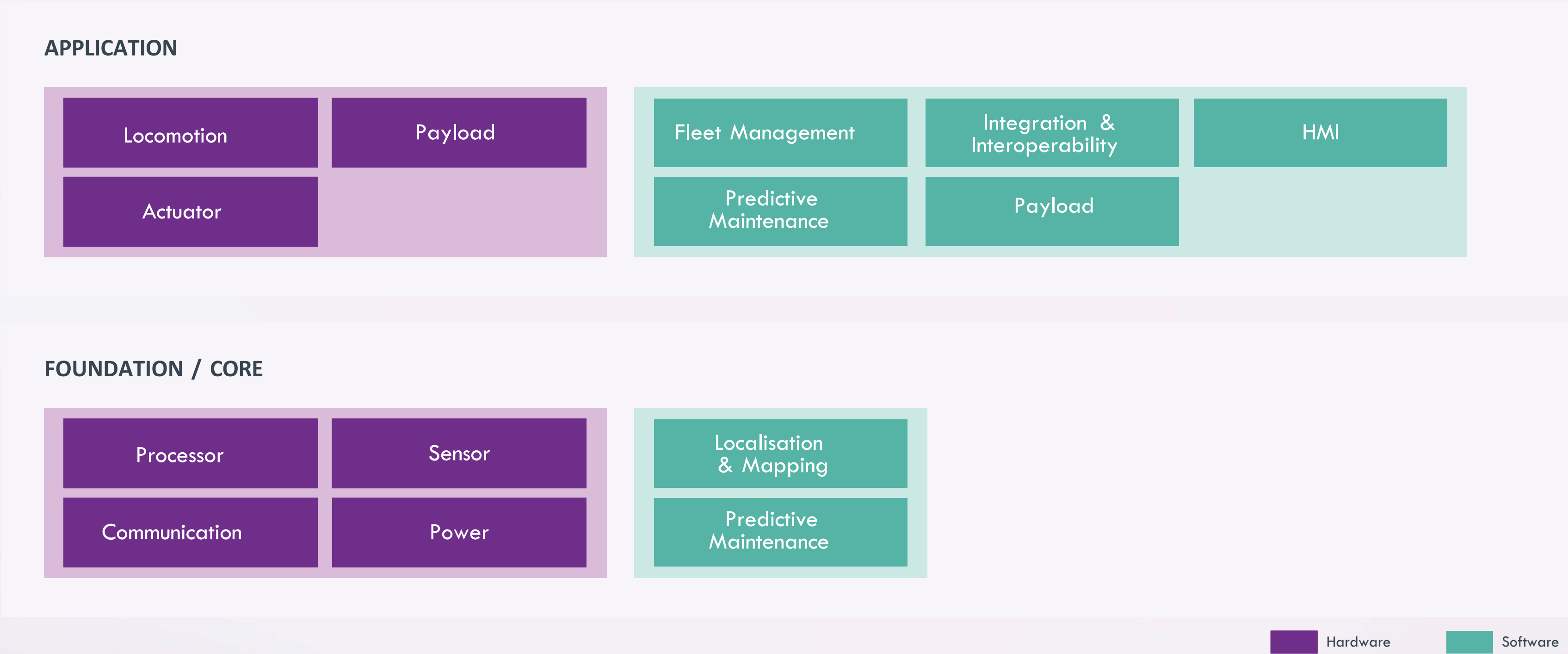


ANNEX

ANNEX A

AMR COMPONENTS – SYSTEM BLOCK DIAGRAM

The following illustrates the high-level system architecture and key components of a typical AMR.



ANNEX A

AMR COMPONENTS – UNDER THE HOOD | **HARDWARE**

The following are the key hardware components of AMRs.

FOUNDATION

PROCESSOR

Control & Compute: The robot’s brain

What it is

Main computing hardware that runs the AMR software, navigation, and control functions.

Why it matters

Processing power affects system performance, sensor processing, and navigation. More complex applications may require higher computing capacity.

SENSOR

Perception: How the robot sees

What it is

Environmental perception for navigation, obstacle detection, and safety.

Why it matters

Sensor choice affects navigation accuracy and reliability. Different environments may require different sensor combinations.

COMMUNICATION

Connectivity: How the AMR talks

What it is

Communication between the AMR, site systems, and infrastructure.

Why it matters

Reliable connectivity is required for monitoring, reporting, and integration. Requirements vary depending on the operating environment.

POWER

Energy: The robots heart

What it is

Power supply and management for AMR operation.

Why it matters

Battery capacity affects runtime and uptime. Requirements vary based on payload, usage, and operating conditions.

APPLICATION

LOCOMOTION

Movement: The robot’s legs

What it is

Movement system for AMR navigation.

Why it matters

The operating environment influences the type of locomotion required. Uneven surfaces, ramps, or tight spaces may require specialised systems.

PAYLOAD

Load: What the robot carries

What it is

Maximum load the AMR can safely carry or transport.

Why it matters

Payload requirements influence AMR selection and configuration. Exceeding payload limits can affect stability and performance.

ACTUATOR

Function: The robot’s arms

What it is

Task execution through lifting, gripping, opening, or dispensing.

Why it matters

Actuator requirements depend on the task being performed. More demanding applications may require greater precision, force, or specialised tooling.

ANNEX A

AMR COMPONENTS – UNDER THE HOOD | SOFTWARE

The following are the key software components of AMRs.

FOUNDATION

LOCALISATION & MAPPING

Control & Compute: The robot's brain

What it is

Determines the AMR's position and builds a map of the operating environment.

Why it matters

Localisation and mapping affect navigation accuracy and reliability. Performance may vary depending on the operating environment.

NAVIGATION & PERCEPTION

Enabling Movement & Task Execution

What it is

Movement planning and environmental perception for task execution.

Why it matters

Navigation and perception affect the AMR's ability to move safely and complete tasks reliably. Performance may vary depending on the operating environment.

APPLICATION

FLEET MANAGEMENT

Coordination & Control

What it is

Monitoring, coordination, and control of multiple AMRs.

Why it matters

Fleet management affects workflow coordination and overall operational efficiency. Requirements increase with fleet size and system complexity.

INTEGRATION & INTEROPERABILITY

Enabling Seamless Execution

What it is

Data exchange and integration between AMRs, infrastructure, and enterprise systems.

Why it matters

Integration requirements vary across systems and vendors. Compatibility issues can affect deployment and operations.

HUMAN MACHINE INTERFACE (HMI)

Interaction with Robot

What it is

User interaction, monitoring, and control of the AMR.

Why it matters

Interface design affects usability and operational efficiency. Poor user experience can lead to errors and inefficiencies.

PREDICTIVE MAINTENANCE

Analytics for Maintenance

What it is

Analysis of operational data to identify potential faults before failure occurs.

Why it matters

Predictive maintenance depends on data quality and system connectivity. Effective implementation can reduce downtime and improve reliability.

COMPUTER VISION

Recognising objects, people, & surroundings

What it is

Visual interpretation of the surrounding environment using camera-based sensing.

Why it matters

Computer vision performance depends on lighting conditions and image quality. Environmental factors can affect detection accuracy and reliability.

ANNEX B

STANDARDS AND RESOURCES

This resource bank highlights standards and resources relevant to AMR deployment, with a focus on safety and operations. It includes international standards, Singapore-specific regulations and resources, as well as explanatory concepts related to AMR implementation. Together, these references help stakeholders make informed decisions during planning and deployment.



International Standards

- ISO 10218-2:2025
- ISO 13850:2015
- ISO/TR 23482-1:2020
- ISO 3691:4-2023
- ISO 8373:2021
- IP ratings
- ISO 12100:2010
- ISO 13842:2014



Singapore Standards & Regulation

- ISO 10218-2:2025
- ISO 13850:2015
- ISO/TR 23482-1:2020
- ISO 3691:4-2023



Explanation of Concepts

- RMF-enabled middleware
- Teleoperations platform



KEY STANDARDS & GUIDELINES | INTERNATIONAL STANDARDS

ISO 10218-2:2025

AMRs — Safety requirements
Part 2: Industrial robot
applications and robot cells

ISO 3691:4-2023

Industrial trucks — Safety requirements and
verification Part 4: Driverless industrial trucks
and their systems

ISO 12100:2010

Safety of machinery — General principles for
design — Risk assessment and
risk reduction

ISO 13850:2015

Safety of machinery —
Emergency stop function —
Principles for design

WHAT DOES IT COVER

Addresses the integration of
industrial robots into a complete
solution, with a focus on the safe
design and integration of
machines and components.

Covers operating environments, hazards and
risks, and the implementation of safety
systems for AMRs.

Provides a structured approach to assess risks
and evaluate whether machinery meets the
required safety requirements for its
intended environment.

Specifies the functional
requirements and design
principles for emergency stop
functions on machinery.

WHY IS IT USEFUL

Helps minimise hazards in
industrial environments where
robots perform complex or
potentially dangerous tasks.

Supports the safe operation of
autonomous systems in environments
shared with people, while managing risks and
maintaining operational efficiency.

Foundational standard for machinery safety,
providing terminology and methodology that other
safety standards build on. Supports alignment on
risk assessment approaches for AMRs.

Creates clear specifications for
emergency stop functions, helping
organisations verify that robot
systems include properly designed
emergency stop devices.

LINKS

International Standard
ISO 10218-2:2025

International Standard
ISO 3691-4:2023

International Standard
ISO 12100:2010

International Standard
ISO 13850:2015



KEY STANDARDS & GUIDELINES | INTERNATIONAL STANDARDS

ISO 8373:2021

AMRs — Vocabulary

ISO 13482:2014

Robots and AMR devices —
Safety requirements for personal care robots

ISO/TR 23482-1:2020

Application of ISO 13482,
Safety-related test methods

IP RATINGS

Ingress protection ratings

WHAT DOES IT COVER

Provides essential terminology that serves as a common language for the AMRs industry.

Specifies requirements for the inherently safe design, protective measures, and information for use of personal care robots.

Provides guidance on applying ISO 13482:2014 to different types of personal care robots, including mobile servant, physical assistant, and person carrier robots.

Defines the ingress protection standards, which grade the resistance of an enclosure against the intrusion of dust or liquids.

WHY IS IT USEFUL

Supports consistent and accurate communication between manufacturers, users, and regulators.

Aids cost-benefit analyses by highlighting safety infrastructure upgrades, maintenance requirements, training needs, and other long-term operating costs.

Helps users identify relevant safety features for different operating environments and use cases, and assess vendor safety claims.

Helps ensure AMRs have an appropriate IP rating for the intended operating environment.

LINKS

[International Standard ISO 8273:2021](#)

[International Standard ISO 13482:2014](#)

[T1 Assessment for AVs on public paths](#)

[Ingress Protection \(IP\) ratings](#)



KEY STANDARDS & GUIDELINES | SINGAPORE STANDARDS AND REGULATION

TR 104-2022

Safe use of autonomous mobile robots (AMRs) in warehouses

TR 108-2022

Safe deployment of robot systems in the healthcare sector

SS 713:2025

Data exchange between robots, lifts and automated doorways to enable autonomous operations

TR 130:2025

Interoperability between central command and/or AMRs middleware and autonomous mobile robots (AMRs) or AMR fleet management (AMR-FM)

WHAT DOES IT COVER

Defines safety requirements for the operation, navigation, and control of AMRs and associated systems operating in warehouses.

Specifies a safety evaluation framework and risk assessment requirements for the safe and sustainable deployment of robot systems in healthcare environments.

Establishes standards for communication between robots, lifts, and automated doorways, regardless of manufacturer or model.

Specifies integration requirements for premises owners, AMR suppliers, and system integrators to support multi-robot fleet deployments within a building or across multiple buildings.

WHY IS IT USEFUL

Helps ensure AMRs are configured to respond safely and appropriately to potential hazards.

In healthcare environments, AMRs interact with vulnerable groups, including patients and elderly visitors. This standard helps address the additional risks present in these dynamic environments.

Facilitates the implementation of AMR solutions in smart multi-storey buildings.

Provides a framework for seamless interoperability across heterogeneous robot fleets in multi-vendor deployments, with a focus on data exchange requirements.

LINKS

[Technical Reference TR 104:2022](#)

[Technical Reference TR 108:2022](#)

[Singapore Standards SS713:2025](#)

[Technical Reference TR 130:2025](#)

ANNEX C

PERFORMANCE METRICS

Track these metrics to objectively assess the success of AMR deployment, support informed decision-making, and identify areas for improvement.

ROBOT

CATEGORY	KEY METRICS	DESCRIPTION
System Usage	System uptime and availability	Operational time vs downtime (i.e. due to charging, faults, etc.)
	Idle time	Non-operating duration due to errors or obstructions
	Distance covered	Total distance covered by the robot
	Power consumption	Duration per full charge and consumption patterns
System Performance	Task completion time	Time taken to complete a task
	Number of system faults	Total system faults encountered
	Number of manual interventions	Instances where a staff assists the AMR, i.e. manually repositioning the robot or overriding navigation
	Number of auto-recoveries	Instances of the system performing an auto-recovery (back to base, recovery after faults)
	Charging efficiency	Time taken to recharge the robot
	Comms signal strength	Signal strength of the network
Safety	Number of safety incidents (robot)	Instances of robot collisions, near-misses, guest complaints, or emergency needs via hotlines.
	Number of auto-recovery	Instances where auto-recovery (i.e. back to base) is being initiated
	Number of emergency stop	Instances of automatic emergency stops
Human-Machine Interface	User comfort score	User acceptance based on survey responses

PRODUCTIVITY & QUALITATIVE

CATEGORY	KEY METRICS	DESCRIPTION
Productivity	Throughput or volume	How many items or units are moved per hour or per shift
	Task completion rate	Percentage of tasks finished correctly and on time
	Cycle time	Time saved per task (e.g., picking, transporting)
	Labor Productivity	Manpower productivity per FM workflow
	Robot utilisation rate	Percentage of time robots are actively performing tasks
	Downtime per robot	Downtime caused by system failures or maintenance issues
Return of Investment (ROI)	CAPEX over useful life (\$)	Annual equivalent cost of the AMR investment over its useful life
	Net Annual Savings from AMRs	Amount of salary savings per year (time freed up)

GLOSSARY

3PL	3 rd Party Logistics	GPUs	Graphics Processing Units
AI	Artificial Intelligence	GTP	Goods-to-Person
AMR	Autonomous Mobile Robot	HMI	Human Machine Interface
API	Application Programming Interface	IP	Ingress Protection
AR/MR	Augmented Reality / Mixed Reality	ISO	International Standards Organisation
BCA	Building and Construction Authority	KPI	Key Performance Indicator
BE	Built Environment	MES	Manufacturing Execution System
BMS	Battery Management System	OBC	Onboard Computer
BMS	Building Management System	RFID	Radio Frequency Identification
CAPEX	Capital Expenditure	RMF	AMR Middleware Framework
CETTRAN	Centre of Excellence for Testing & Research of Autonomous Vehicles – NTU	SFMS	Shuttle Fleet Management System
DMEs	Digitally Mature Enterprises	SOP	Standard Operating Procedure
ESG	Enterprise Singapore	SOW	Scope of Work
FM	Facilities Management	TR	Technical Reference
FTE	Full-Time Equivalent	UAT	User Acceptance Test
GNSS	Global Navigation Satellite System	UI	User Interface
GPS	Global Positioning System	WMS	Warehouse Management System



Connect with us to find out more about how IMDA can help your company in leveraging emerging technologies to support your digital transformation journey.

ABOUT IMDA

The Infocomm Media Development Authority (IMDA) leads Singapore's digital transformation with infocomm media. To do this, IMDA will develop a dynamic digital economy and a cohesive digital society, driven by an exceptional infocomm media (ICM) ecosystem — by developing talent, strengthening business capabilities, and enhancing Singapore's ICM infrastructure.

IMDA also regulates the telecommunications and media sectors to safeguard consumer interests while fostering a pro-business environment and enhances Singapore's data protection regime through the Personal Data Protection Commission.

For more news and information,
visit www.imda.gov.sg or follow IMDA on Facebook IMDAsg and Twitter @IMDAsg



© Infocomm Media Development Authority (IMDA)

First published in 2026 by IMDA

10 Pasir Panjang Road #03-01, Mapletree Business City, Singapore 117438