MOTUS HANDLING

Automated Storage and Retrieval Systems

(ASRS – Automated Warehouses)

A Motus Handling Perspective

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Purpose

Comparison of crane-based automatic warehouses, mother-child shuttle systems, and 3D shuttle systems from a practical material-flow and automation perspective.

1 Contents

2 Introduction

2.1 What is ASRS?

Automated Storage and Retrieval Systems (ASRS) are computer-controlled warehouse solutions that automatically store and retrieve pallets, containers, or boxes. By combining racks, conveyors, lifts, software, and control systems, ASRS improves storage density, throughput, traceability, and labor efficiency.

At Motus Handling, ASRS is viewed not merely as a storage technology but as part of an integrated material-flow solution. Very often Motus Handling adds material flow up and downstream of the ASRS.

Successful automation requires reliable pallet quality, accurate product identification, efficient transport systems, and intelligent warehouse control software. Motus Handling offers a solution for each.

2.2 Three ASRS solutions

This paper compares three major ASRS concepts:

1. **Crane-based automatic warehouses** - storage and retrieval by stacker cranes operating in dedicated aisles.
2. **Mother-child shuttle systems** - high-density deep-lane systems using a mother shuttle and child shuttle combination.
3. **3D shuttle systems** - four-way shuttles capable of moving in multiple directions and between storage areas.

2.3 Summary

Crane systems are the most mature and proven technology.

Mother-child systems offer high-density storage with modular expansion.

3D shuttle systems provide maximum flexibility and scalability but require greater control sophistication and rack precision.

3 Methodology

3.1 Scope

This paper evaluates ASRS concepts for pallet-based warehouses from a Motus Handling material-flow perspective.

The document is intended as an evaluation framework, not as a final engineering design, supplier selection, or investment calculation.

3.2 Evaluated technologies

- **Crane-based ASRS**: stacker-crane systems operating in dedicated aisles.
- **Mother-child shuttle systems**: deep-lane systems using a mother shuttle and child shuttle combination, supported by lifts or elevators.
- **3D shuttle systems**: multi-directional shuttle systems designed for flexible routing, scalability, and distributed redundancy.

3.3 Excluded technologies

The following alternatives are not compared in detail: conventional manual racking, semi-automated pallet shuttle systems without full ASRS control, AGV/AMR-fed storage, external storage, hybrid concepts, mini-load systems, carton shuttle systems, and non-pallet unit-load automation.

3.4 Scoring criteria

The comparison uses a simple qualitative score for these decision points:

- How much storage space the system can use.
- How many pallets the system can move, and how predictable this is.
- How well the system fits the product mix and changing flows.
- How proven the technology is, and how much risk there is in implementation.
- What happens when something fails, and how easy it is to repair.
- How the investment, future expansion, software, and rack accuracy affect the choice.

3.5 Limitations

- This is a high-level assessment. It does not replace a detailed study, simulation, supplier quote, or TCO calculation.
- Actual performance depends on the layout, pallet quality, SKU mix, peak flows, lift capacity, software rules, maintenance access, and supplier design.

3.6 Summary comparison table

Criteria	Crane-Based ASRS	Mother-Child Shuttle	3D Shuttle
Storage principle	Stacker crane in a dedicated aisle	Mother shuttle brings child shuttle to deep storage lanes	Autonomous shuttle moves in multiple directions across a grid
Storage density (number of units per m^3)	High	Very high	Very high
Throughput (number of pallets or units handled per hour)	High and predictable throughput, based on clearly calculable crane cycles per aisle.	Very high throughput when repeatedly moving pallets in and out of deep lanes with the same SKU or batch.	Very high, scalable throughput by adding shuttles and rerouting movements as demand changes.
Best fit for low or high number of SKUs?	High number	Medium to high number	Very high number
Pallet selectivity (ability to retrieve any pallet directly)	Excellent	Moderate	High to Excellent(1)
Redundancy	Medium: one crane per aisle	High: multiple shuttles possible	Very high: multiple independent shuttles
Failure impact	Failure affects one aisle	Usually affects one shuttle or zone	Generally limited to one shuttle
Technology maturity	Highest	High	Medium to high (2)
Rack tolerance sensitivity (risk of positioning errors, jams, downtime, and wear if rack alignment or levelness is not within specification)	Medium	Medium	High
Investment threshold (3) (indicative number of pallet positions from which the technology usually becomes worthwhile)	Typically worthwhile already for small warehouses.	Typically worthwhile from larger deep-lane buffers or storage blocks, e.g. roughly 5,000–8,000+ pallet positions, especially with repeated flows per SKU or batch.	Typically worthwhile from larger and more dynamic warehouses, where flexibility, scalability, and redundancy justify the higher starting complexity.
Main advantage	Proven, reliable, highly mature technology (4)	Excellent density and modular expansion	Maximum flexibility and scalability for storing larger number of units.
Main limitation	Throughput tied to crane capacity per aisle	More complex than crane systems	Highest software and rack-precision requirements

(1) Depending on lane depth, storage strategy, shuttle density, lift availability, and sequencing rules

(2) Shuttle maturity varies by supplier, reference base, software maturity, installed systems, and service capability

(3) The pallet-position thresholds above are indicative only. The investment case depends on total cost of ownership, expected throughput, labor reduction, building height and footprint, energy cost, maintenance concept, and the possibility to expand the system later.
(4) Crane ASRS remains the longest-established

4 Executive summary

Requirement	Recommended technology
Lowest technical risk	Crane-Based ASRS
Highest storage density	Mother-Child or 3D Shuttle
Highest flexibility	3D Shuttle
Most mature technology	Crane-Based ASRS
Best phased expansion strategy	Mother-Child Shuttle
Best for uncertain future growth	3D Shuttle
Best for deep-lane storage	Mother-Child Shuttle
Best for highly dynamic SKU profiles	3D Shuttle
Best overall for stable pallet warehouses	Crane-Based ASRS

Motus Handling recommendation:

When customer demand is predictable and long-term reliability is the primary objective, a crane-based ASRS remains the preferred solution.

When high-density storage and phased growth are key drivers, a mother-child shuttle system offers the best balance between investment and performance.

When flexibility, scalability, and future uncertainty dominate the business case, a 3D shuttle system can be the strongest option, provided that the number of units is high enough to justify the higher initial investment in this complex technology.

Motus Handling therefore focuses primarily on medium-sized warehouses, where crane-based ASRS and mother-child shuttle systems often provide the best balance between technical complexity, investment level, and operational value.

5 Crane-based automatic warehouses

5.1 Architecture

5.1.1 Summary

A crane-based ASRS consists of racks and an automated pallet stacker cranes traveling in dedicated aisles. The crane moves horizontally and vertically and uses telescopic forks or other load-handling devices to store and retrieve pallets.

5.1.2 Product flow step by step

1. Arrival at the warehouse.
2. Identification and quality inspection.
3. Pallet validation or rejection.
4. Transfer to crane pick-up station.
5. Crane travel to target location.
6. Storage using telescopic forks.
7. Confirmation in the WMS.

5.1.3 Details

Telescopic forks allow single- or double-deep storage, increasing storage density while maintaining aisle accessibility. Crane systems are suitable for pallet warehouses, mini-load warehouses, and cold-storage environments.

Picking warehouse with pallet stacker cranes, custom designed by Motus Handling

5.2 Technology

5.2.1 Failure dependency

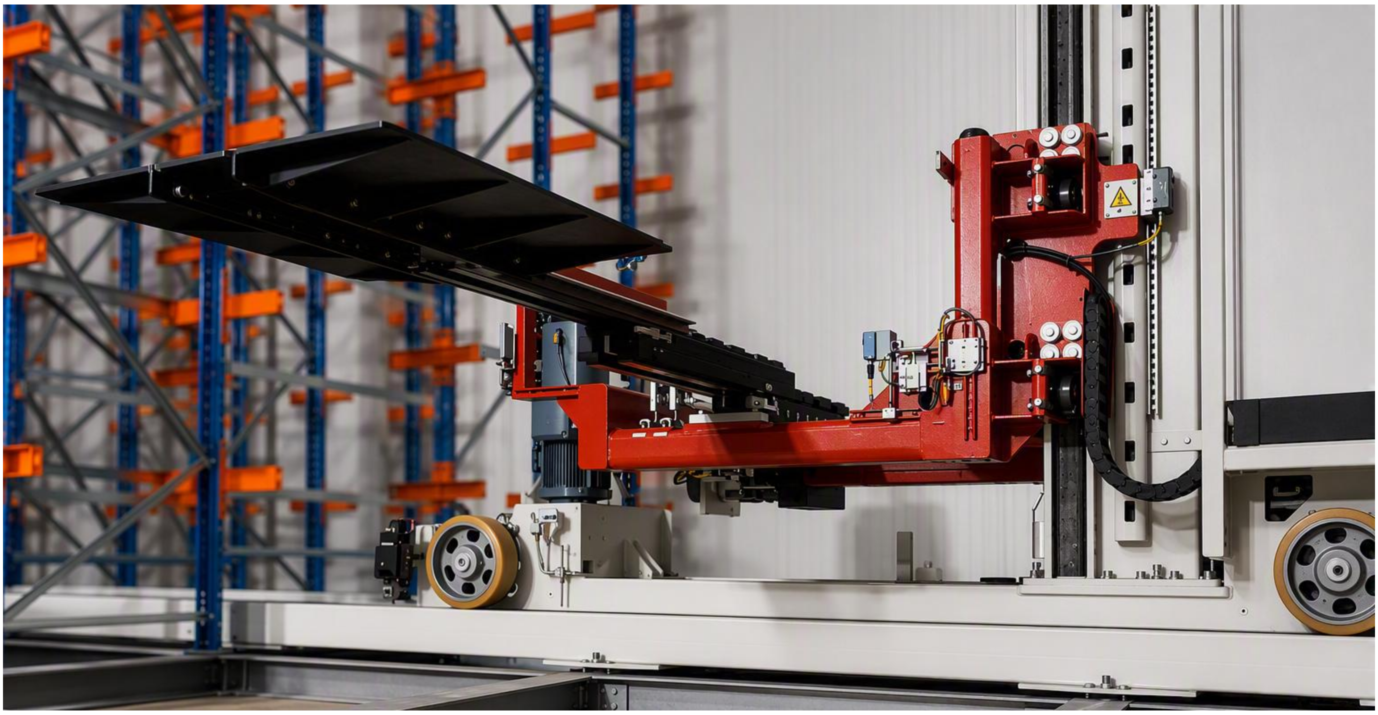
A crane failure generally impacts only its own aisle.

5.2.2 Repair and complexity

Crane systems are mechanically straightforward and well understood within the industry. Typical interventions include isolating the affected aisle, bringing the crane to a safe maintenance position, checking drives, sensors, forks, wheels, cables, and controls, and restarting the aisle after functional testing. If a component fails, it is usually repaired or replaced directly on the crane, while the other aisles can continue operating.

5.2.3 Maturity

This is the most mature ASRS technology with decades of industrial use.



Motus Handling's Crane with telescopic arm

6 Mother-child shuttle systems

6.1 Architecture

6.1.1 Summary

Mother-child shuttle systems are also known as 2D deep-lane shuttle systems. A mother shuttle moves along the main aisle while a child shuttle enters storage lanes to place or retrieve pallets.

6.1.2 Product flow step by step

1. Pallet arrives and is inspected.
2. Elevator transfers pallet to the correct level.
3. Mother shuttle transports the pallet to the target lane.
4. Child shuttle enters the lane.
5. Pallet is stored in the assigned position.
6. Retrieval follows the reverse process.

6.1.3 Details

The elevator forms the interface between warehouse levels and the shuttle system.

Configurations may use one mother shuttle per level, shared mother shuttles between levels, multiple child shuttles per mother shuttle, and additional lifts for increased throughput.

6.2 Technology

6.2.1 Failure Dependency

Failures are distributed among several vehicles rather than one central machine.

6.2.2 Repair and Complexity

More moving components create higher system complexity than crane systems. Frequent interventions include repairing the lift or replacing lift components, removing a mother shuttle for repair or replacement, and repairing or replacing the child shuttle when it fails inside a lane. If a shuttle stops because of an empty battery, it must be recovered safely, recharged, or replaced by a charged unit before the lane or level is released again.

6.2.3 Maturity

Mother-child technology is widely used for dense pallet storage and production buffers.

6.3 Design by Motus Handling

6.3.1 Shuttle design by Motus Handling

Motus handling designed a child shuttle able to carry a payload of 2,5 ton.

6.3.2 Mother/Child Warehouse design by Motus Handling, 80 meters wide, 55.000 pallet locations

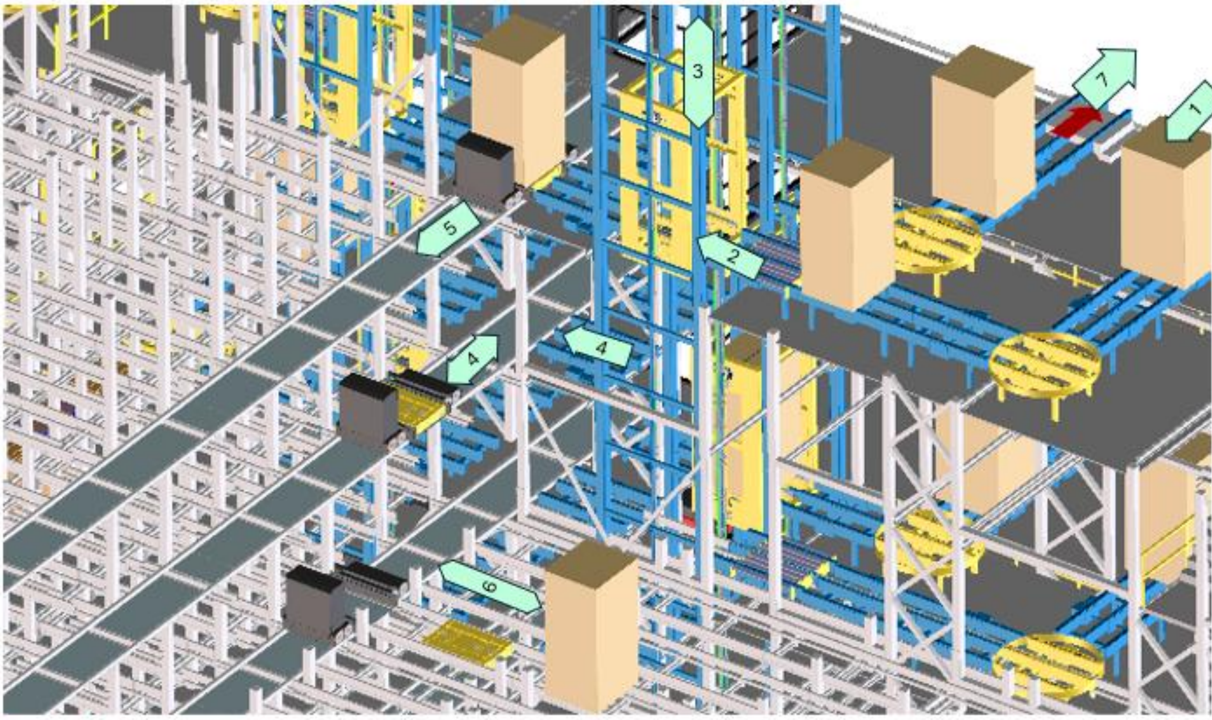


Figure 1 *Mother/Child warehouse system designed by Motus Handling (80 meters wide, 55.000 pallet locations).*

Operating sequence

1. Pallet infeed from the buffer area (dual-level infeed).
2. Transfer to the vertical lift.
3. Vertical lift transports the pallet to the assigned storage level.
4. Pallet pickup by the mother/child shuttle at the lift interface.
5. Mother/child shuttle transport to the assigned storage lane.
6. Child (satellite) shuttle stores the pallet in the designated lane position.
7. Pallet retrieval follows the reverse sequence.
8. Dedicated shuttle lift for maintenance and shuttle repositioning between levels.

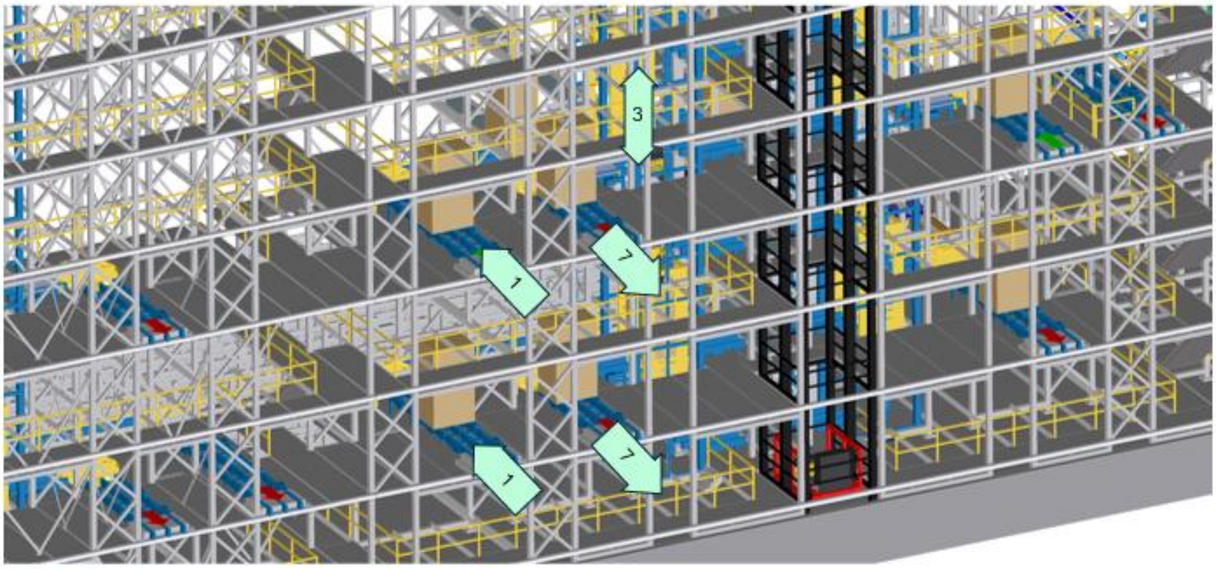


Figure 2 *Front view.*

7 3D Shuttle systems

7.1 Architecture

7.1.1 Summary

3D shuttle systems use autonomous shuttles capable of moving both longitudinally and laterally.

7.1.2 Product flow step by step

1. Pallet arrives and is validated.
2. Lift transports pallet to the required level.
3. Shuttle receives the pallet.
4. Shuttle moves through the warehouse grid.
5. Pallet is stored in the designated position.

7.1.3 Details

The lift serves as the interface between conveyors and shuttle levels.

Unlike mother-child systems, 3D shuttles can move freely across multiple storage zones, creating greater routing flexibility.

7.2 Technology

7.2.1 Failure dependency

Failures are generally localized to individual shuttles.

Rack precision is critical. Because the shuttle travels directly on rails integrated into the racking structure, deviations in perpendicularity, levelness, or rail alignment can directly affect throughput, reliability, and maintenance requirements.

7.2.2 Repair and complexity

Maintenance is more software-intensive and technically demanding than crane systems. Typical interventions include repairing lift faults, removing a failed shuttle from the grid for repair or replacement, recovering shuttles with empty batteries, and freeing jammed shuttles or blocked routes. Because several shuttles interact dynamically, repair work usually requires both mechanical access and software-controlled isolation of the affected zone.

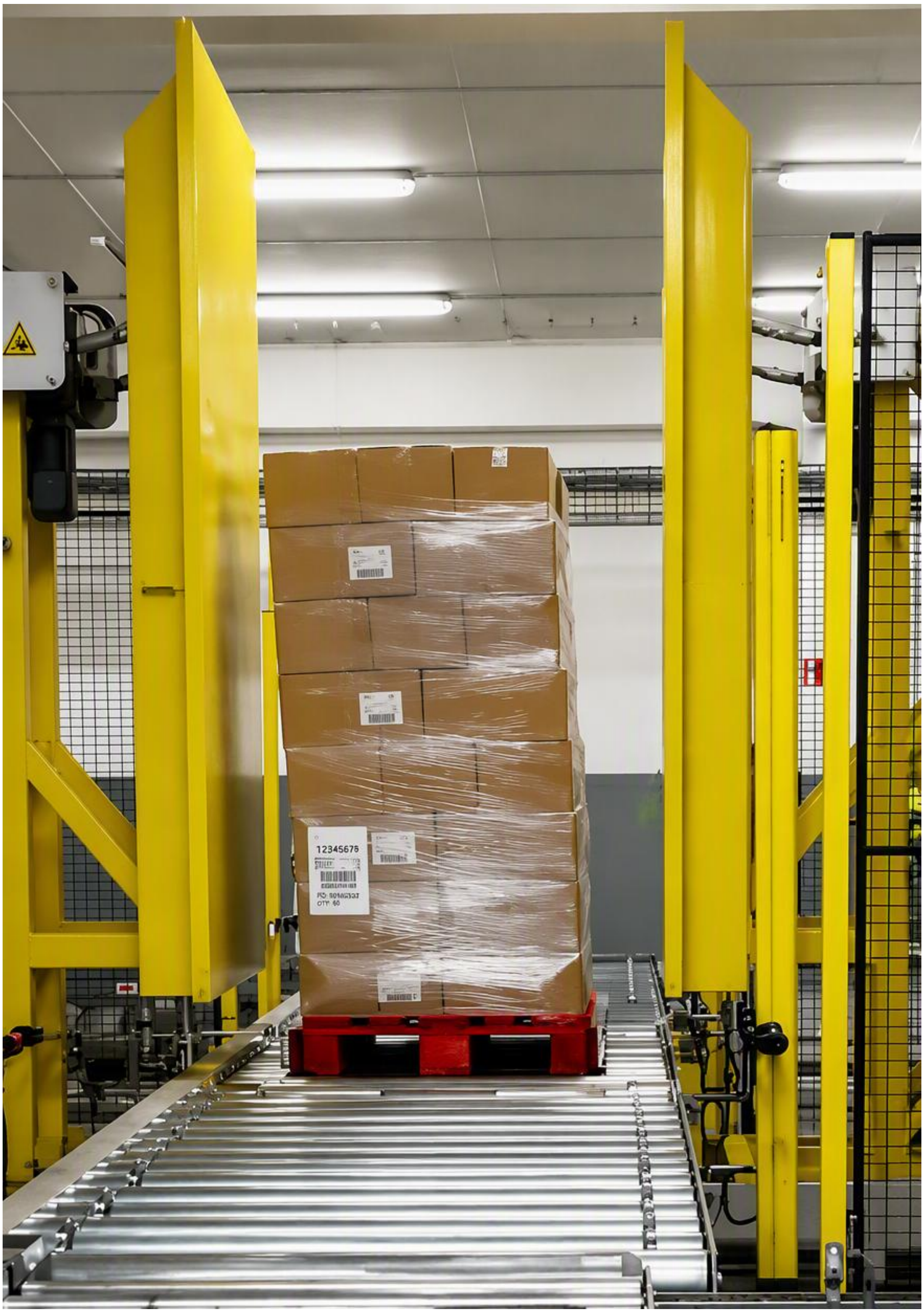
7.2.3 Maturity

The technology is commercially proven but requires high supplier maturity in this technology.

8 Conditions for correct automation

8.1 Pallets within tolerance

Successful automation starts with pallet quality. Pallets that exceed dimensional tolerances can cause storage failures, conveyor jams, and safety risks.



Motus Handling's Squeezer to correct out-of-tolerance pallets

Motus Handling addresses this through its Pallet Squeezer, which automatically corrects pallet contours before storage or shipment.

8.2 Pallets not damaged

Damaged pallets are a major source of downtime in automated warehouses.

Motus Handling provides solutions such as:

- Pallet inspection systems
- Damaged pallet detection
- Pallet correction stations
- Slave pallet solutions
- Pallet inverters

These systems ensure only compliant pallets enter the automated process.

Motus Handling's Automatic pallet control and sorting system, one of the solution designed by Motus Handling to cope with damaged pallets.

9 Conclusion

Each ASRS technology has a distinct application area, and the right choice depends on the required storage density, throughput, product-flow pattern, number of units, investment threshold, and maintenance concept.

- **Crane-based ASRS** remains the choice with lowest technology novelty risk in many stable pallet warehouse applications.This is particularly relevant when reliability, technology maturity, predictable crane-cycle throughput per aisle, and straightforward repair are the main priorities.

- **Mother-child shuttle systems** are best suited for high-density deep-lane storage with repeated pallet flows per SKU or batch, where the higher complexity of lifts, mother shuttles and child shuttles is justified by the available volume and modular expansion potential.

- **3D / four-way shuttle systems** should remain part of the evaluation for highly dynamic or expansion-driven cases. Within Motus' preferred scope and risk profile, crane-based ASRS and mother-child shuttle systems are often the preferred concepts for stable, medium-sized pallet warehouses. Four-way shuttle systems can still be considered through supplier partnerships.

From the Motus Handling perspective, successful ASRS automation is therefore not only a technology choice. It also requires compliant pallet quality, reliable infeed and outfeed flows, robust WMS/WCS integration, realistic ROI assumptions, and a maintainable design that matches the customer's scale, risk tolerance, and long-term growth path.

Visit www.motushandling.be to see how Motus Handling supports reliable, future-proof warehouse automation.