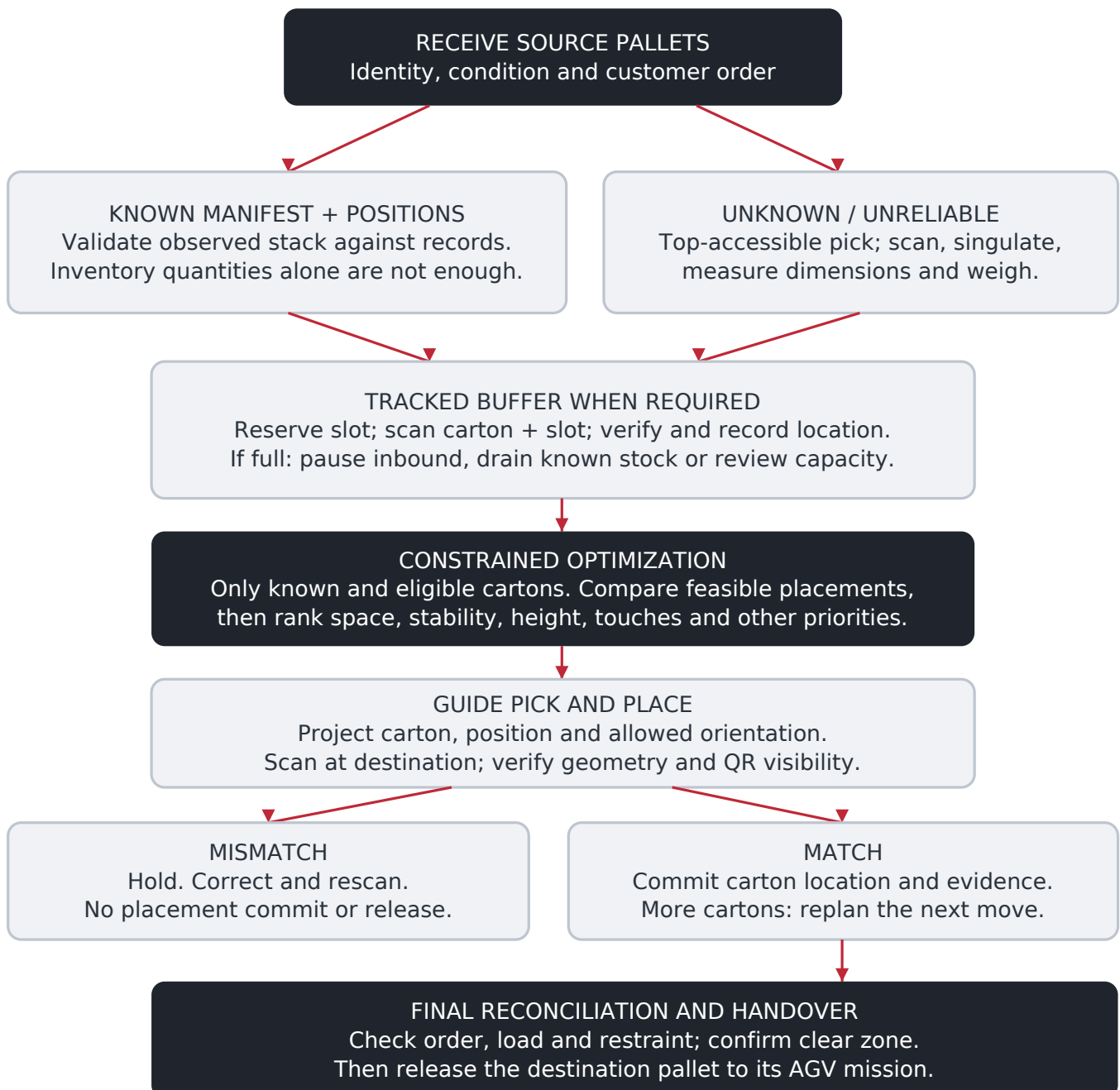




01 / PROCESS FLOW

From mixed inbound to verified load

A configurable guided palletizing platform for rigid cartons. It plans where to pick, where to stage and how to build a destination pallet.



Known sources can feed the destination directly when feasible; buffering is not mandatory. Unknown full-batch discovery needs space for the whole discovery batch. Rework loops retain the original transaction.



02 / OPERATING CHOICES

Choose the knowledge strategy

The correct design depends on what is genuinely known before picking and how much temporary storage the site can provide.

Mode	What is known / how it works	Trade-off
Known source	Verified carton data AND 3D source poses. Expose buried cartons through tracked temporary moves.	Best opportunity to plan ahead with fewer measurements; stack changes must be reconciled.
Unknown, rolling	Identify a limited batch, record each slot, then place only those measured cartons. Repeat.	Smaller buffer and earlier output. Later items may fit poorly; pallet splitting may be needed.
Unknown, full batch	Discover every carton, then resequence the known batch.	More planning freedom, but more buffer space and at least two handling moves per staged carton.

Buffer capacity is a system constraint

A buffer must have known occupancy, a size / weight envelope and a reserved location for every inbound carton. Physical slots and usable area both matter. A full-batch plan needs capacity for the declared batch; unknown inbound cannot rely on a fictitious overflow area.

Worked demo, not a throughput promise: each seeded wave contains 48 mixed cartons. Known-source planning can use selective staging, whereas full-batch unknown discovery needs all 48 addressed positions and requires 96 moves (source to buffer, then buffer to destination). Rolling discovery uses less initial capacity but can need extra pallets. Use the in-app comparison for results under the selected weights and limits; these are not warehouse capacity recommendations.

Practical recommendation

Start with known-source or rolling discovery for a manual-guided trial. Compare full-batch discovery when enough buffer is available. Measure cube efficiency alongside touches, pallet count, operator travel and throughput. An extra-pallet decision must be explicitly authorized by the customer order policy.

Planning estimates for the physical trial: buffer demand depends on batch size, accessible blockers, replenishment bursts and recovery allowance. Average work-in-progress estimates do not prove that finite peak capacity is sufficient.



03 / OPTIMIZATION

Feasible first. Efficient second.

A high weighted score never excuses an unsafe or impossible placement. Hard constraints are checked before objective ranking.

Hard constraints in the demo	Engineering meaning
Geometry and access	Actual dimensions; no collision or overhang; top-accessible source picks; only allowed 0/90 degree yaw.
Support and load transfer	Minimum contact area; carton centre above the support polygon; cumulative loads transmitted to lower cartons.
Order, payload and location	Correct destination order; configured height / weight limits; unique carton identity; no untracked or overfilled buffer.
Selectable objective	What it changes
Space / lower height	Favor tighter actual load envelopes and lower stack profiles.
Stability / lower exposure	Prefer support and balance; reduce height / edge exposure proxies.
Value / payload / quantity	Adjust item sequence and feasible candidate preference within the fixed order.
Fewer touches / lower buffer use	Penalize unnecessary staging; release occupied positions when useful.
Layer overlap	Reward actual multi-box contact, not merely a 90-degree rotation.

Algorithm and honest limits

The demo compares eight candidate ordering heuristics. Each uses exact edge-aligned positions, allowed rotations and constraint filtering. Complete feasible orders take priority; normalized weights then rank the trade-offs, including estimated staging. No 50 mm placement grid or global-optimum claim. Completed placements are locked; unknown cartons are excluded until measured.

Interlocking is not automatically superior to column alignment. Use validated carton compression / stackability data, support conditions, friction and load-restraint tests. The model uses approximate area-based load transfer; it does not simulate cardboard deformation or transport dynamics. The exposure index is NOT a probability of falling.



04 / DATA AND CONTROL

One carton. One trusted location.

Projection gives instructions. Scanning identifies the item. Vision verifies placement. The database commits the accepted physical result.

Record	Required fields / purpose
Carton and master data	Carton ID; SKU; actual L/W/H; weight; order; lot / expiry; permitted orientation; fragile / stackability / validated top-load rating.
Source and observation	Source pallet ID; carton pose; observation time; sensor confidence; occlusion / accessibility; actual versus expected state.
Buffer and reservation	Slot ID; pose; size / weight capacity; occupancy; reserved transaction; quarantine status.
Placement and pallet	Destination order / pallet ID; XYZ / yaw; sequence; supporting cartons; weight; plan revision; locked status.
Move and evidence	Unique move ID; from / to; actor; phase; scan results; observed geometry; error / correction links; timestamps.

Commit sequence

Reserve carton and target location -> verify pick ID -> confirm physical move -> measure if unknown -> scan target -> verify placement -> commit location. On mismatch, retain the reservation and evidence. On restart, reconcile observed stock with the last committed transaction; never replay a move blindly.

Production integration boundary

Use durable transactional records, unique event keys, idempotent WMS/WCS exchanges and explicit acknowledgement / timeout states. PLCs and safety controls remain responsible for machine permissives. A projector or ordinary camera is not a safety-rated interlock.

The delivered app uses local memory, synthetic measurements and structured simulated evidence. It has no production database, central image retention or live equipment connection. Export before reset. Weight and dimensions do not reveal carton compression strength; obtain that separately from validated master data.



05 / PHYSICAL DESIGN

A modular logistics platform

Reusable software does not mean one mechanical cell can handle every product. Declare the material, dimensional and operational envelope first.

Base cell

Four source conveyor pallet positions and four forklift-AGV destination docks. Every source and destination point has two broad-field projectors, an independent Vision unit and overhead QR reading: 16 projectors, 8 Vision units and 8 scanners. Measurement and buffer verification need additional coverage sized to the layout.

Optical and operator details

Recalibrate the projected surface as stack height changes. Coordinate / blank projection during optical capture. Preserve QR face-up within allowed carton orientations; hidden or damaged labels need another view or relabelling. Position the buffer to reduce travel and unsafe reaches. Consider lift assistance where the manual handling assessment requires it.

Application	Fit / additional work
Mixed rigid cartons	Good candidate: retail replenishment, service parts, mixed-case distribution, returns and consolidation. Validate labels, stackability and order rules.
Manual-guided operation	Flexible handling; still constrained by load, reach, frequency, visibility and operator access. The 25 kg demo input is not an approved lifting limit.
Robot-assisted discovery	Consider for repeatable singulation. Validate grasping, suction surfaces, reach, payload, collision avoidance, damaged cartons and exception handling.
Bags, drums, loose / hazardous goods	Outside the current cuboid model. Need new geometry, compatibility rules, handling tools and process validation.

The 3D transfer animation communicates process order only. It is not a robot program, validated robot trajectory, grasp simulation or safety model. Packaging materials, restraint and transport conditions must be tested physically before release rules are approved.



06 / TRIAL AND NEXT DECISIONS

Prove the whole workflow

Test known and unknown inbound, not only a perfectly arranged pallet. Measure packing benefit against the cost of staging and recovery.

Trial dimension	Acceptance evidence to agree
Data and recognition	Actual source poses available? Mixed sizes; covered labels; wrong QR; duplicate ID; damaged carton; uncertain measurement.
Packing quality	All order items accounted for; no collisions or unsupported placements; approved top-load limits; volume utilization; pallet count; height.
Buffer and recovery	Peak occupied slots; full-buffer hold; source pause; correct slot on retrieval; extra touches; power / connection loss reconciliation.
Execution and safety	Operator reach / travel; measured throughput; load restraint; transport tests; clear-zone handover; physical safety assessment.

Information needed from the customer

1. Carton range and sample orders, including size, weight and stackability.
2. Source knowledge: exact carton poses, or only a packing list?
3. Available layout, buffer area, headroom and operator access.
4. Order-split policy, shipping priorities, pallet sizes and transport limits.
5. WMS/WCS interface specification, event IDs and recovery expectations.
6. Measurable cycle-time, quality and load-stability acceptance criteria.

Suggested development sequence

Begin with a configurable manual-guided proof of concept using representative cartons. Add measured discovery and tracked buffering. Compare rolling versus full-batch planning. Introduce robot-assisted singulation only after the handling and exception trials show a clear benefit.

Reference basis (accessed 10 September 2026)

HSE - Pallet safety, PM15: pallet suitability, load distribution, restraint and inspection.

GS1 - Logistic Label Guideline: logistics-unit identification and label design.

GS1 - EPCIS: a reference event model for interoperable traceability.

The above sources inform the proposed design; this guide does not claim regulatory compliance or GS1 conformance. Demo QR labels encode carton IDs and are not an SSCC implementation.