REFLEX WHITEPAPER

Why shop-floor hardware comes before manufacturing software

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SUBJECT

SMB manufacturing

SCOPE

Shop-floor hardware

Summary

Small manufacturers build hardware and run their operations on paper. Without instrumentation, the software they buy has no accurate data to work from, so it goes unused.

This paper defines three levels of shop-floor hardware, **capture**, **integration**, and **edge intelligence**, and what each one enables. Scheduling, capacity planning, and any model all depend on the system knowing what happened on the floor.

US manufacturing firms that are small	Firms with fewer than 20 employees	Robots per 10,000 workers, US	Manufacturing jobs needed by 2033
98%	**75%**	**307**	**3.8M**
SBA Office of Advocacy	Of all manufacturers	South Korea: 1,220	~1.9M may go unfilled

Key findings

- **Capture is not optional.** Keyed entry runs about one error per 300 characters; scanned entry runs about one per three million.
- **Planning has hard input requirements.** Capacity planning needs routings, live quantities, and process definitions. Without them, a shop cannot schedule.
- **The US under-automates relative to its peers.** At 307 robots per 10,000 manufacturing employees, the United States sits behind South Korea, Singapore, and Germany.
- **Edge hardware is no longer the barrier.** A module delivering 40 TOPS costs $249. The barrier is that most floors have no recorded data for a model to learn from.

Who builds in America

The shape of the market

Small firms account for 98% of US manufacturing firms, and roughly 75% employ fewer than twenty people. Manufacturers under 500 employees account for 4.8 million workers, about 40.9% of manufacturing employment. The federal MEP network reaches around 36,000 of them a year, and reports $24.6 of new sales for every federal dollar spent.

The automation gap

The United States installs fewer robots per manufacturing worker than South Korea, Singapore, or Germany.

Robots per 10,000 manufacturing employees

2024 · higher is more automated

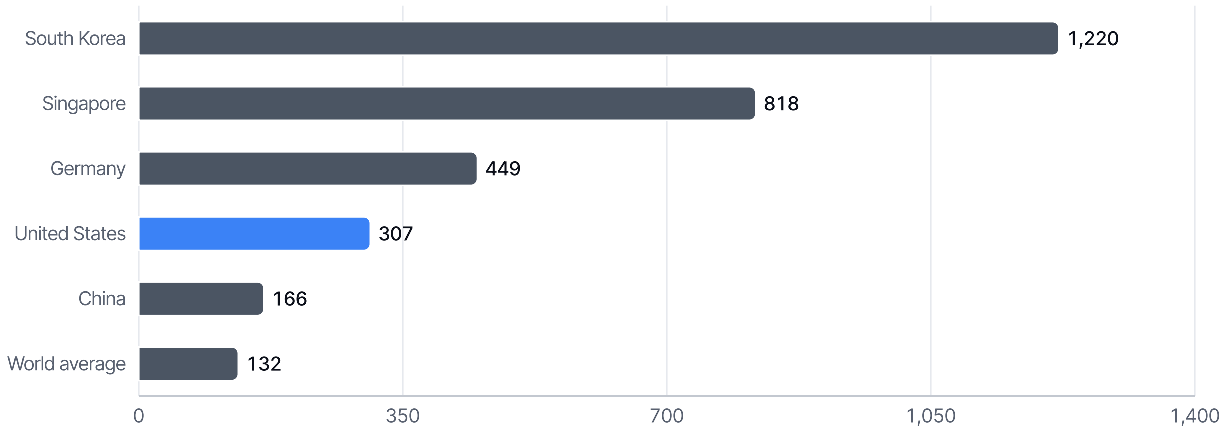

Figure 1. Robot density by country. Industrial robots per 10,000 manufacturing employees, 2024 data.

Source: International Federation of Robotics, World Robotics 2025.

Deloitte and The Manufacturing Institute project that manufacturing could need as many as 3.8 million new workers by 2033, with roughly 1.9 million of those roles going unfilled if nothing changes.

The maturity ladder

Three levels, adopted in order. Each level depends on the data produced by the one below it.

Level 3
Edge intelligence →
Can the floor act on what it sees without waiting for a person?
Edge inference hardware on the line: vision for inspection and count, models that flag drift as it appears.

Level 2
Integration →
Does the equipment report to the system without a person in the loop?
Machine data over MTConnect or OPC UA, scales and gauges wired to the order they belong to.

Level 1
Capture →
Does the system know what actually happened on the floor?
Scanning stations at receiving, stock, production, and packing. Labels on every item and location.

Figure 2. The three levels. Each level answers a different question and unlocks a different class of work.

Level 1: Capture

Scanning stations at receiving, stock, production, and packing, with barcode or RFID tags on every item and every location. Handheld scanners cover moves away from a station; fixed RFID readers at dock doors and cell entrances record movement with no operator action. Operators need no login. They scan, and the system records what moved and when.

Barcode is cheaper per tag and needs line of sight. RFID costs more per tag and reads a full pallet at once, so it fits receiving and shipping, where material arrives in bulk.

Every read becomes an event with a time, a place, and a quantity. Stock by location and order status are calculated from those events, so they change the moment material moves. Figure 3 follows one pallet of pistons from the dock to a shipped order without a single typed entry.

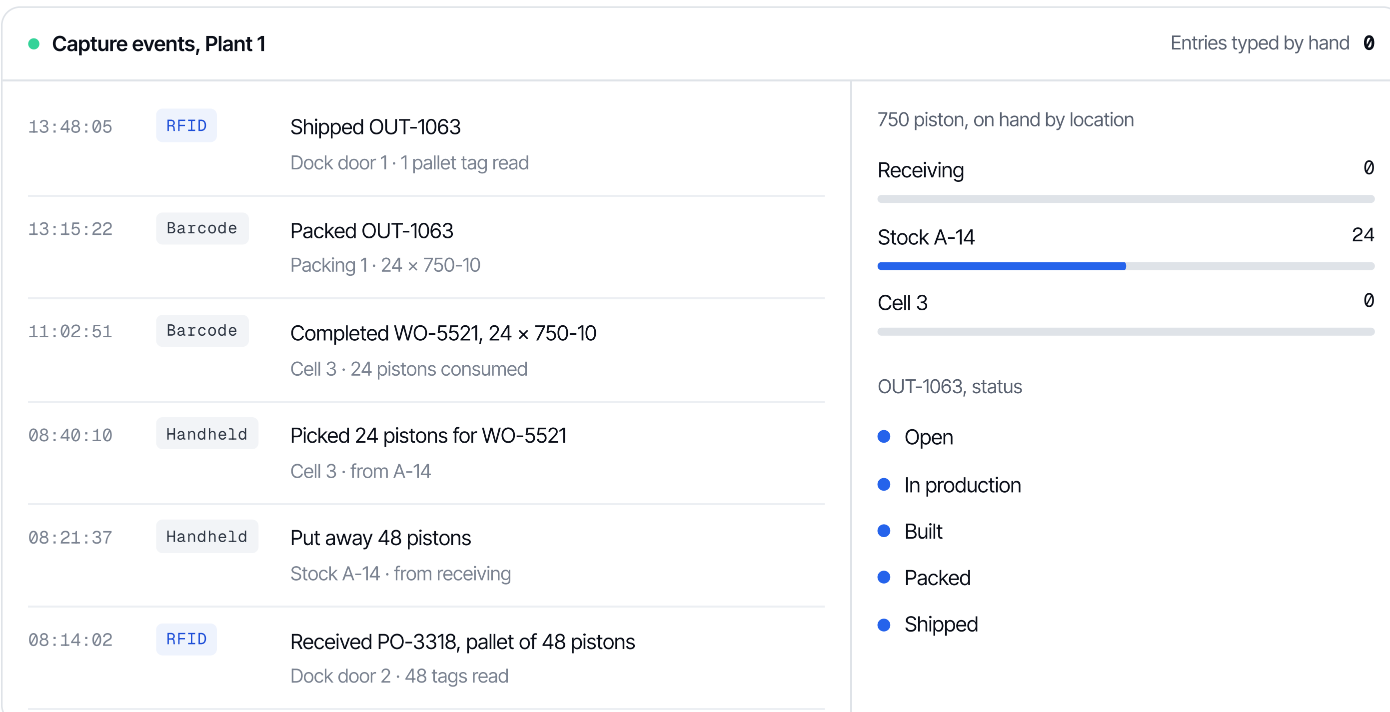

Figure 3. From reads to records. RFID portals at the dock doors and scanners at stock, the work cell, and packing each post an event. Stock by location and order status update from the events alone. Drawn illustration.

Figure 4. Capture hardware. A handheld scanner covers moves away from a station. Fixed barcode and RFID readers sit where material already stops: receiving, stock, production, packing.

Source: Photograph by 1sfoerster, CC BY-SA 4.0, via Wikimedia Commons.

Level 2: Integration

Equipment reports for itself. Machine state arrives over MTConnect or OPC UA, scales and gauges post to the order they belong to, and run times are measured instead of estimated. Both standards have been public since 2008, and OPC UA is an IEC standard.

Utilization is measured, scrap is posted when it happens, and capacity reflects the machines on the floor.

Level 3: Edge intelligence

Inference runs at the line. Cameras count and inspect parts, models flag drift, and exceptions surface during the run instead of after it. The hardware is inexpensive: an NVIDIA Jetson Orin Nano delivers up to 40 TOPS at $249 within a 5–15 W envelope, and an AGX Orin module reaches 275 TOPS.

Table 1. Edge inference modules

MODULE	AI PERFORMANCE	POWER	PRICE
Jetson Orin Nano	40 TOPS	5–15 W	$249
Jetson AGX Orin	275 TOPS	15–60 W	$3,499 (dev kit)

Manufacturer-published specifications and pricing, accessed September 2026.

What each level buys

Accuracy of capture

Keyed entry and scanned entry differ by about four orders of magnitude in error rate.

Table 2. Error rates by capture method

METHOD	OBSERVED ERROR RATE
Manual keying	1 error per 300 characters
Barcode scanning	1 error per 3,000,000 characters

Widely cited industry benchmark figures rather than a single named study; the relative magnitude, not the exact denominator, is the point.

In Zebra's survey of 1,400 warehouse decision-makers, 32% reported using RFID, with a further 39% planning to adopt within a year.

RFID adoption

Percent of respondents

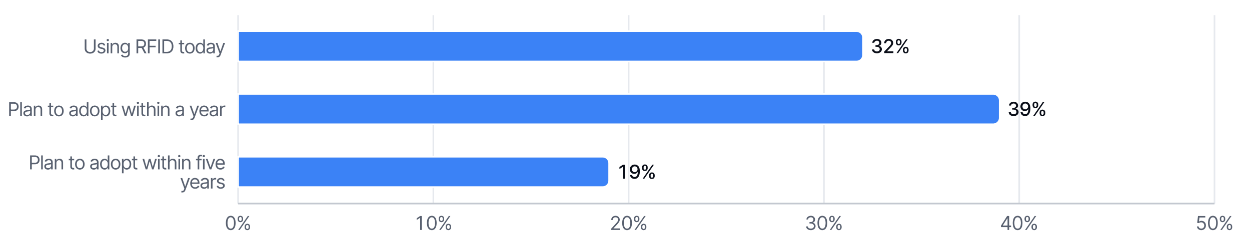

Figure 5. RFID adoption among warehouse operators. Share of 1,400 decision-makers surveyed across manufacturing, retail, transport, and wholesale.

Source: Zebra Technologies, Warehousing Vision Study, 2023.

What planning requires

ASCM’s manufacturing planning and control framework separates priority planning from capacity planning, and capacity planning requires inventory data, master schedule data, and engineering and routing data, adjusted for scrap and rework.

A shop without Level 1 cannot supply those inputs reliably, which is why scheduling modules in ERP systems often sit unused.

Measuring the floor

Overall equipment effectiveness multiplies three numbers: how much of the scheduled time a machine was available, how fast it ran while available, and how much of what it made was good. A plant at 85% is considered world-class. Most discrete manufacturers run 55 to 65%, and only about 3 to 6% of plants reach the world-class mark.

A shop cannot compute any of the three without Level 2. Availability needs machine state, speed needs cycle counts, and quality needs scrap posted against the run that produced it.

Overall equipment effectiveness

Percent

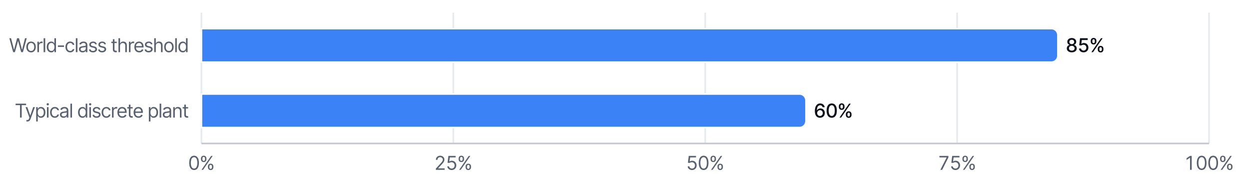

Figure 6. OEE, world-class versus typical. Percent. World-class is the Nakajima threshold used in total productive maintenance.

These OEE ranges are industry benchmarks, not results from a single survey. A shop should measure its own line before setting a target.

Why shops stall at zero

Level 1 is inexpensive. Shops stall because software is sold assuming the data already exists.

A scheduling module assumes routings. An inventory module assumes counts. A quality module assumes recorded results. Without the stations that feed them, those modules ask for data nobody has, and the shop goes back to spreadsheets.

Reflex installs the stations first, as part of the system: fixed barcode and RFID readers where material already stops, labels printed by the system that reads them, and no operator login. Integration and edge intelligence follow on the same data model.

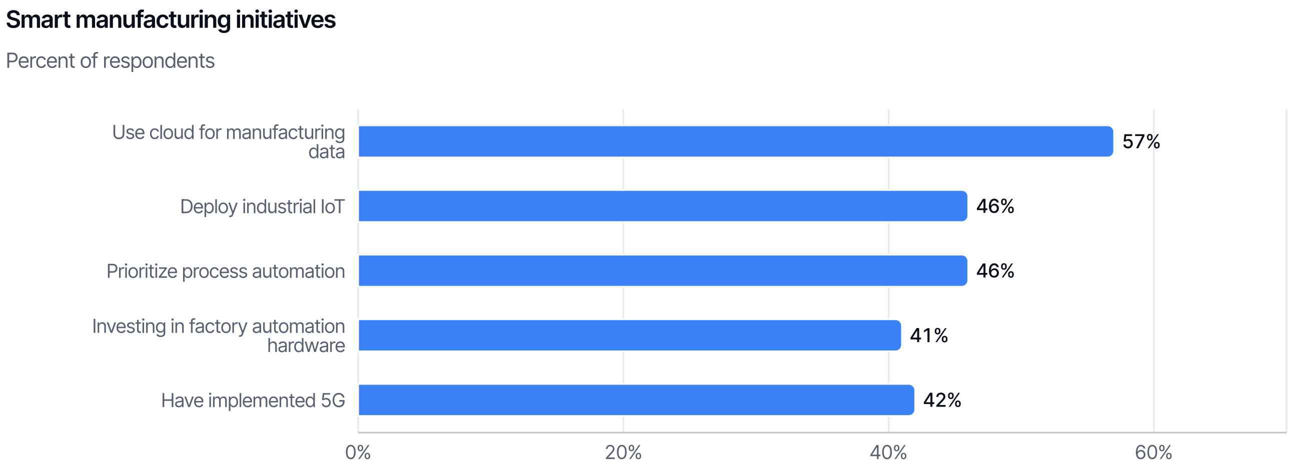

Figure 7. Where manufacturers are investing. Share of 600 manufacturing executives reporting each initiative.

Source: Deloitte, 2025 Smart Manufacturing and Operations Survey.

Notices & references

On the figures

Where a number comes from a vendor survey or a widely repeated industry benchmark rather than an independent study, this paper says so on the page. Claims that could not be traced to a credible source, including the share of small manufacturers still working on paper, and generalized returns from machine-monitoring case studies, are omitted rather than estimated.

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