AI's impact on Japanese manufacturing industry

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CPS Evolution and Technical Democratization

- Cyber-physical systems (CPS)
  - CPS connect physical operations with digital representations, analysis, and control. Digital twins, model-based engineering, and technologies for exchanging industrial data provide a foundation for coordinating design, production, and service across organizational boundaries.
- Broader access through AI
  - AI opens a further possibility: broader access to these capabilities. Natural-language interfaces and AI-assisted, low-code or no-code tools could enable more engineers and operators to participate in model development, automation, and robot deployment. AI can help more people use engineering tools and discover new solutions.
- Human-Centered CPS Integration
  - AI solves pre-defined problems, but humans must establish the target value, ethical boundaries, and comprehensible decision frameworks.

Human centric 2.0 –Sustainable future-

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- Focus
  - Leverage Human abilities in the manufacturing industry
  - Enhancing the well-being of workers
- Vision
  - With the philosophy of acknowledging and respecting human diversity, we will create a human-centric and sustainable next-generation manufacturing system where everyone can work with initiative and creativity, feel a sense of satisfaction and achievement, and support each individual who participates in the engineering process or production system with empathy. In such a system, people and systems can grow together.



http://humancentric.race.t.u-tokyo.ac.jp

- Human-Oriented Manufacturing & Engineering System (HOMES)
  - Accompanies and works alongside individual workers, thinks together, respects their decision-making process, and provides support.
  - Supports all diverse workers without leaving anyone behind
    - Each worker differently experiences well-being even when executing the same tasks in the same environment
    - Everyone has their own strength and weakness



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Outline

- **Fact-Based Diagnosis of Japan's Position**
  - Analyzing digital investment gaps, legacy hardware constraints, and local optimization and limited system-wide integration.
- **Uncovering the Hidden Growth Potential**
  - How can Japan’s challenges become opportunities to leapfrog?
- **The Dual-Pillar AI Transformation Strategy**
  - Combining AI-assisted front-loading (MBE) with upgraded Genba capability via AI-native CPS.

Japan’s position 1: digital gaps

Cross-company data sharing

75.1% Japan 19.8% US 27.0% Germany

Report no data sharing or provision to other companies (2025).

IPA, DX Trends 2025, p. 34 (https://www.ipa.go.jp/digital/chousa/dx-trend/tbl5kb0000001mn2-att/dx-trend-2025.pdf)

Private AI investment

$0.93bn Japan $109.1bn US

2024, all industries. Financing, rather than factory adoption spending.

Both comparisons cover all industries.

Cabinet Secretariat, 22 April 2026, p. 2 (https://www.mext.go.jp/content/20260514-mxt_chousei02-000049865_11.pdf)

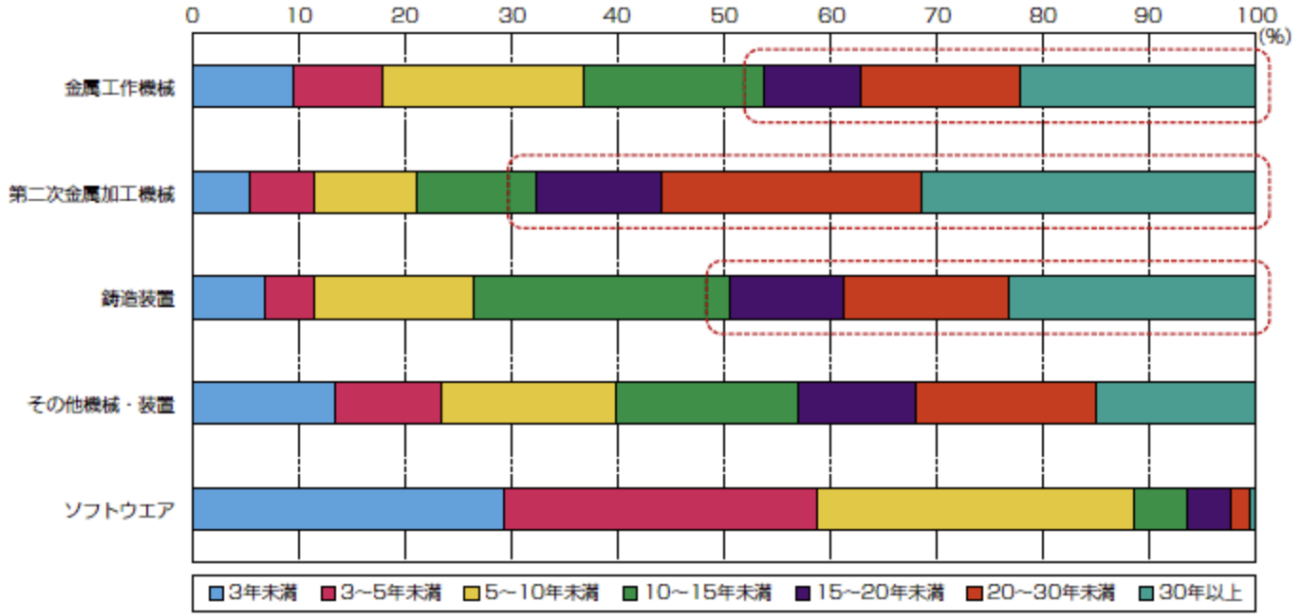
Japan’s position 2: legacy assets and workflows

~50–80%

Equipment at least 15 years old

Selected metalworking and casting equipment categories, 2018 survey.

図113-8　生産設備導入からの経過年数（2018年調査）



資料：日本機械工業連合会2018 年度生産設備保有期間実態調査（ビンテージ調査）

METI, Manufacturing White Paper 2020, Fig. 113-8 and briefing p. 17. Historical surveys, not current shares.

Inherited equipment and workflows can raise the cost of integrated redesign.

Japan's position 3: Local optimization and limited system-wide integration

- Case study: Managing Environmental Variations in Component Assembly
  - Approach A: Downstream FIX
    - Local Adjustment via Custom Jigs
      - Measure property changes under varying temperature/humidity conditions at assembly, prepare multiple custom jigs, and manually swap jigs during production to maintain accuracy.
  - Approach B: Upstream integration
    - Robust System Design
      - Anticipate thermal/humidity variations during product design and engineer the product to function robustly against variations from the outset.

- Japan's strong shop-floor capabilities can encourage reliance on local adjustments (Approach A). Yet this is not always optimal. Predictable, recurring variation should first be addressed through robust design (Approach B).

JILPT, Research Series 267, Figs. 1–2. Nov–Dec 2024; n = 3,313; 11 industries; 30+ employees.

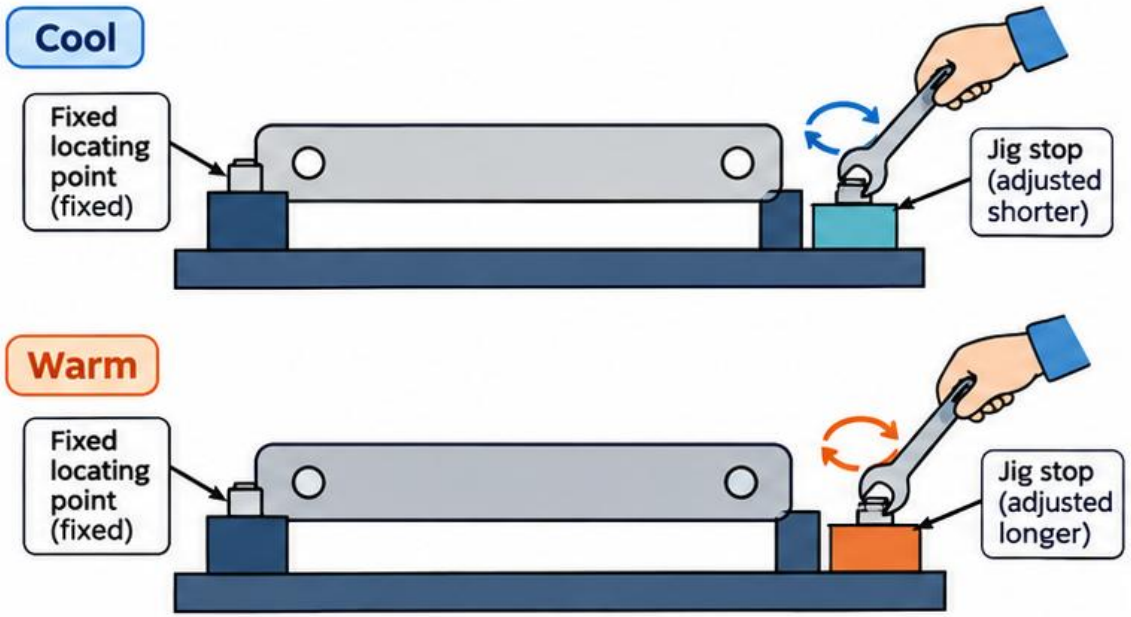
Managing Temperature Variation in Assembly

Illustrative example — not a company case study



A | Compensate on the shop floor

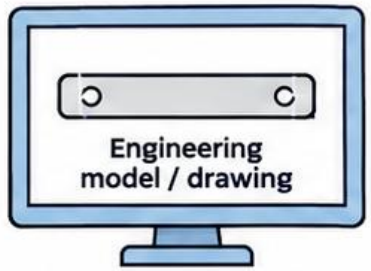
Measure → adjust jig → assemble



Repeat adjustments as conditions change

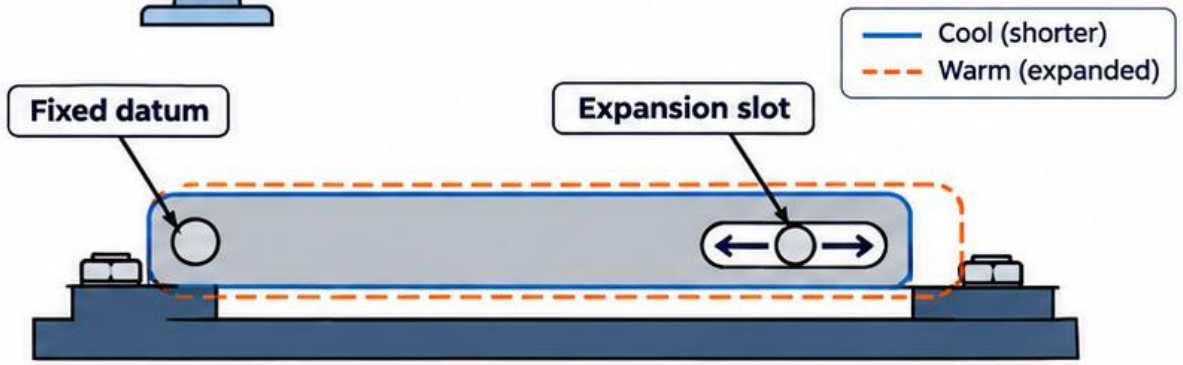
B | Design for variation upstream

Model variation → design tolerance → validate



Robust mounting design

- **ROUND** datum hole + locating pin (left) establishes the reference datum.
- **LONGITUDINAL SLOT** + pin (right) allows differential thermal expansion.



Maintain the datum; accommodate expansion

Prevent recurring problems by design. Apply shop-floor expertise to what remains.

Japan’s position 3: Local optimization and limited system-wide integration (cont.)

Digital improvement by activity

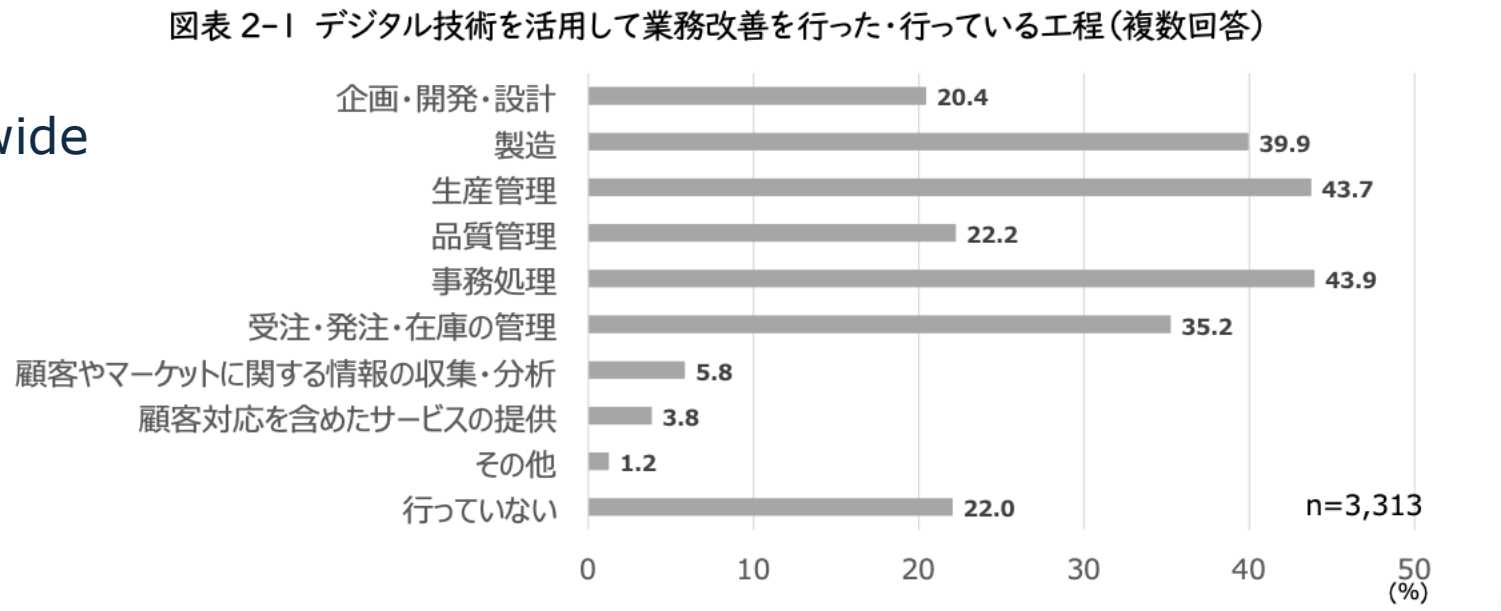
20.4% Planning, development, and design

39.9% Manufacturing 43.7% Production management

About 1 in 3

digitally active firms report process-wide redesign (e.g., optimization via automation)
in manufacturing or production management.

JILPT, Research Series 267
(https://www.jil.go.jp/press/documents/20250509.pdf
Figs. 1–2. Nov–Dec 2024; n = 3,313; 11 industries;
30+ employees.



Interpretation: local gains require much stronger links to upstream system design.

Japan's position 3: Local optimization and limited system-wide integration (cont.)

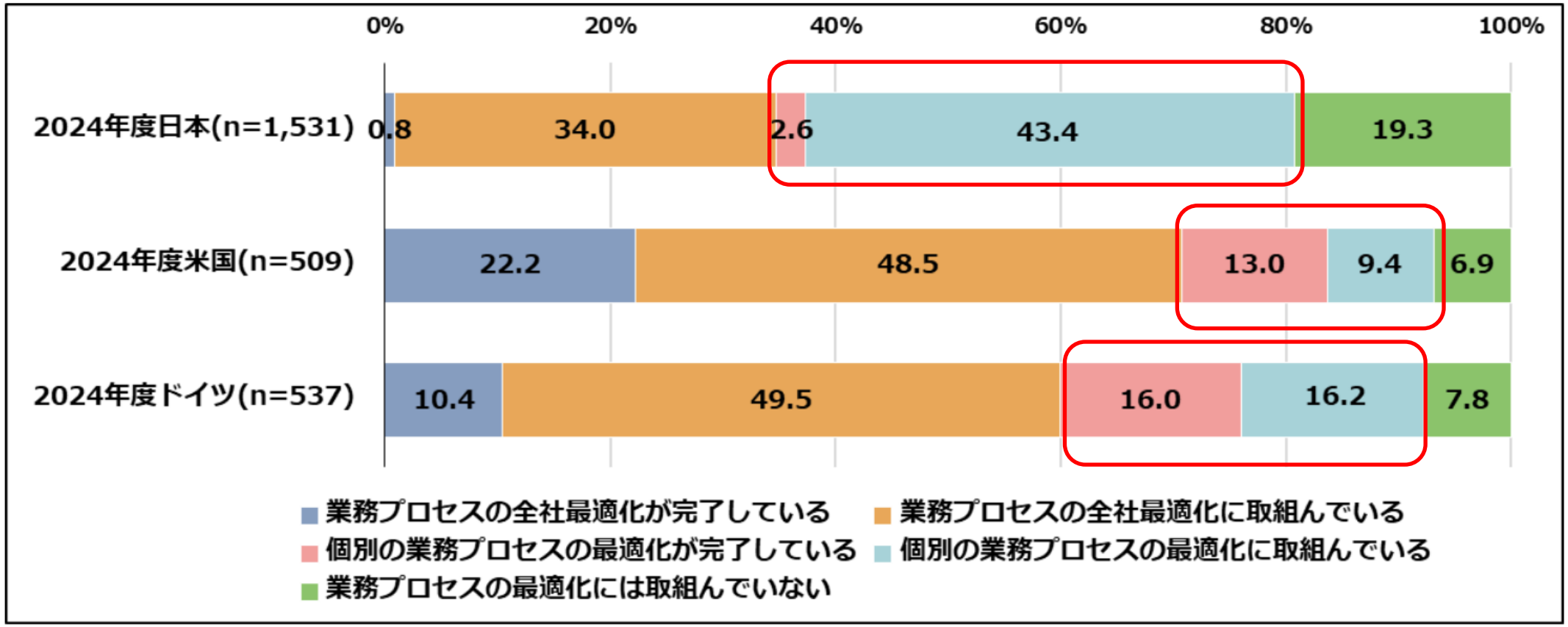
- Local Optimization Remains More Common than Company-Wide Optimization
  - Japanese firms undertaking DX are more likely to optimize individual business processes than to pursue company-wide optimization.

Approach to business process optimization	Japan	United States	Germany
Optimization of individual business processes	46%	22.4%	32.2%
Company-wide optimization of business processes	34.8%	70.7%	59.9%

Scope: DX-engaged firms across all industries—not manufacturing alone. Japan: n = 958; United States: n = 439; Germany: n = 415.
Source: IPA, DX Trends 2025, p. 19, Figure 1-22. Survey conducted February–March 2025 (https://www.ipa.go.jp/digital/chousa/dx-trend/tbl5kb0000001mn2-att/dx-trend-2025.pdf)

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図表 1-22　業務プロセス最適化への取組（国別）



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Existing capability provides a basis for growth

~1.3×

Nominal value added per worker

Manufacturing versus Japan’s all-industry average, 2023.

220 categories

Japanese firms held ≥60% global share

Japanese firms collectively held at least 60% of the global market in 220 surveyed product categories in 2020.

Hypothesis: removing these constraints could release substantial potential.

METI, Manufacturing White Paper 2025, p. 2; JETRO citing Manufacturing White Paper 2023 (2020 market data).

AI transformation strategy (Pillar 1)

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- Hypothesis 1: AI could enable Japanese firms to leapfrog toward system-level optimization
  - **Traditional barrier**: Established tools and engineering workflows
    - Conventional model-based engineering requires substantial investment, specialist skills, and changes to established ways of working.
  - **AI leapfrog opportunity**: AI-assisted modeling and system redesign
    - AI could lower these barriers, helping engineers translate shop-floor knowledge into models, evaluate system-wide trade-offs, and resolve problems upstream.
  - **Potential advantage for Japanese manufacturing**:
    - By adopting AI-native engineering environments and redesigning workflows around them, Japanese firms could turn accumulated production knowledge into a competitive advantage in system-level design and optimization.

AI transformation strategy (Pillar 2)

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- Hypothesis 2: AI could extend shop-floor kaizen into factory-wide improvement
  - **Existing strength:** Hands-on improvement
    - Workers refine fixtures, feeders, and mechanisms to address problems that upstream design cannot fully anticipate.
  - **Current barrier:** Connecting physical improvements to the wider system
    - Integrating these changes with robots, control logic, and production systems requires additional expertise.
  - **AI-enabled opportunity:** Digitally shared and integrated kaizen
    - AI-native CPS could help workers capture improvements digitally, validate their wider effects, and integrate them into factory controls and shared engineering models.
  - **Potential advantage for Japanese manufacturing**
    - Japan’s shop-floor capabilities could generate improvements that extend across the factory and feed back into future system design.

The leapfrogging hypothesis for Japan

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1. Leapfrog toward system-level design and optimization

AI could lower the barriers to model-based engineering and workflow redesign, helping Japanese firms use shop-floor knowledge to prevent problems upstream.

2. Extend shop-floor kaizen across the factory

For problems that remain, AI-enabled CPS could help workers integrate physical improvements with controls, production data, and shared engineering models.

3. Create value through human-centered CPS

People define worthwhile goals, evaluate system-wide trade-offs, and validate changes. AI supports their engineering judgment and creativity.

Japan's opportunity: combine stronger upstream design with digitally integrated kaizen to build a new competitive advantage.

A strategic hypothesis: success requires investment, workflow redesign, and human validation.