Volume 1

CHAPTER 8

Grades of Automation (GoA 0–4)

Communications-Based Train Control
A Comprehensive Guide for US Transit Professionals
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Chapter Overview

- GoA is the most consequential strategic decision in any CBTC project — it determines staffing, cost, regulation, and scalability
- GoA and CBTC are NOT synonymous: CBTC enables higher GoA but is a signaling technology, not an automation level
- IEC 62290-1 defines five GoA levels (0–4), each with distinct responsibility allocations
- GoA 2 (Semi-Automatic) dominates US deployments; GoA 4 (Unattended) is the frontier globally
- Section 8.5 provides a decision framework integrating labor, regulatory, financial, and technical factors

8.1

GoA Framework and Definitions

What Is GoA and Why It Matters

- GoA codifies WHO does WHAT: setting train in motion, stopping, door closure, obstacle detection, disruption response, evacuation
- Enables procurement clarity, safety certification scoping, labor negotiation, and public communication
- Always specify GoA level (0–4) — avoid ambiguous terms like "automatic" or "driverless"
- GoA 0: fully manual, no ATP — GoA 1: manual with ATP — GoA 2: ATO with driver — GoA 3: driverless with attendant — GoA 4: unattended
- Safety case complexity scales with GoA: GoA 3–4 require 2–3x more analysis and 6–12 months longer certification

GoA Responsibility Matrix (IEC 62290-1)

Function	GoA 0	GoA 1	GoA 2	GoA 3	GoA 4
Setting train in motion	D	D	D	Auto	Auto
Stopping train	D	D	D/ATP	Auto/ATP	Auto/ATP
Door closure	D	D	Auto	Auto	Auto
Obstacle detection	Manual	ATP	ATP/ATO	Auto	Auto
Disruption response	D	D	D	A	C/Auto
Passenger evacuation	D	D	D	A	C/Auto

GoA 0–4 Responsibility Matrix

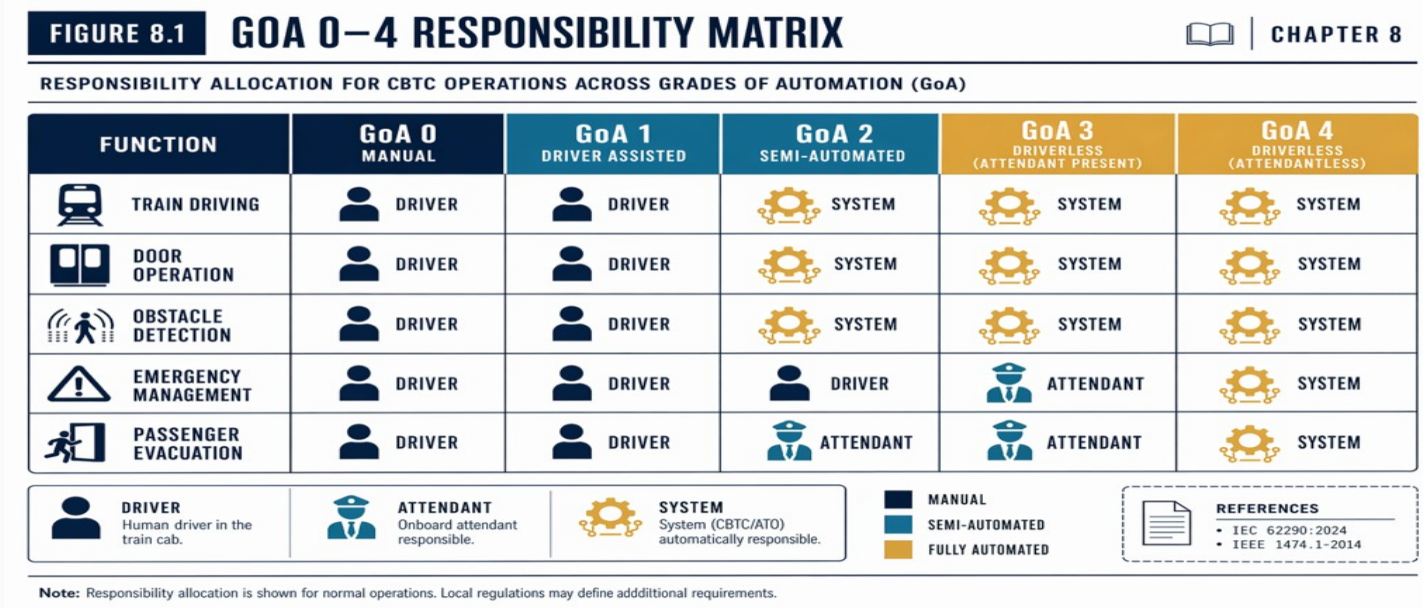

FIGURE 8.1 GOA 0–4 RESPONSIBILITY MATRIX

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RESPONSIBILITY ALLOCATION FOR CBTC OPERATIONS ACROSS GRADES OF AUTOMATION (GoA)

FUNCTION	GoA 0 MANUAL	GoA 1 DRIVER ASSISTED	GoA 2 SEMI-AUTOMATED	GoA 3 DRIVERLESS (ATTENDANT PRESENT)	GoA 4 DRIVERLESS (ATTENDANTLESS)
TRAIN DRIVING	DRIVER	DRIVER	SYSTEM	SYSTEM	SYSTEM
DOOR OPERATION	DRIVER	DRIVER	SYSTEM	SYSTEM	SYSTEM
OBSTACLE DETECTION	DRIVER	DRIVER	SYSTEM	SYSTEM	SYSTEM
EMERGENCY MANAGEMENT	DRIVER	DRIVER	DRIVER	ATTENDANT	SYSTEM
PASSENGER EVACUATION	DRIVER	DRIVER	ATTENDANT	ATTENDANT	SYSTEM

DRIVER — Human driver in the train cab.

ATTENDANT — Onboard attendant responsible.

SYSTEM — System (CBTC/ATO) automatically responsible.

MANUAL

SEMI-AUTOMATED

FULLY AUTOMATED

REFERENCES

- IEC 62290:2024
- IEEE 1474.1-2014

Note: Responsibility allocation is shown for normal operations. Local regulations may define addditional requirements.

Figure 8.1 — Visual representation of responsibility allocation across the five Grades of Automation.

GoA Progression Ladder

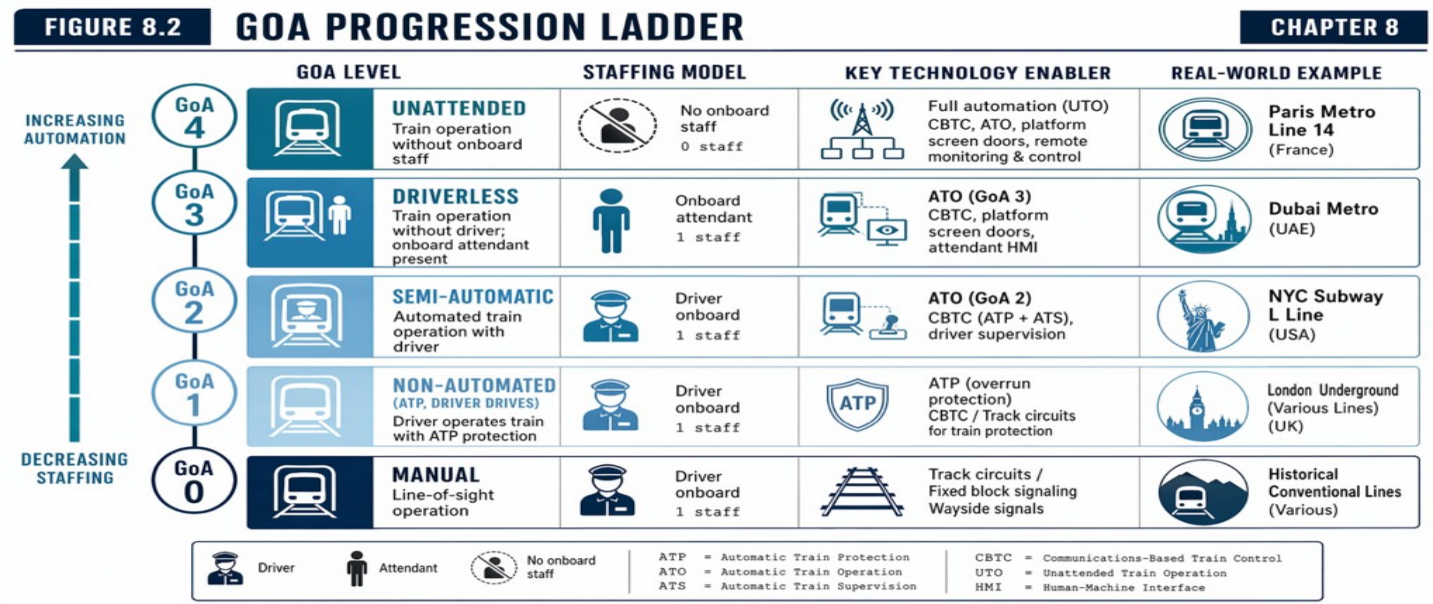

Figure 8.2 — From GoA 0 (fully manual) to GoA 4 (unattended): increasing automation, decreasing human involvement.

8.2

GoA 2: Semi-Automatic Train Operation

Why GoA 2 Dominates US Transit

- Labor unions: preserves operator role — TWU Local 100 (NYC), BLET, and equivalents negotiated ATO operator agreements
- Regulatory acceptance: FTA and state safety agencies have mature frameworks for GoA 2; GoA 3–4 require new pathways
- Gradual automation strategy: validate ATO reliability over 2–3 years, then evaluate upgrade path
- Cost savings: avoids platform screen doors ($8–12% capital) and advanced obstacle detection required for GoA 3–4
- Public perception: operator-in-cab model gains municipal support and rider trust

GoA 2 Driver Role and ATO Authority

- ATO controls: acceleration, speed regulation, coasting, precision braking (±0.3 m)
- ATO tracks target speed profile with PI regulator, energy-optimized coasting
- Comfort limits: ≤1.0 m/s² acceleration, ≤0.5 m/s³ jerk rate
- Energy savings: 10–15% vs. manual driving through optimized coasting

- Driver retains: door operation, emergency brake, mode transitions, fallback driving
- Both ATO and driver retain emergency brake authority
- Training: 400–600 hours (30–50% longer than manual-drive training)
- Annual recurrent training: 16 hrs + 5–10 simulated failure scenarios

GoA 2 Performance Benefits

10–15%

Energy savings vs. manual driving

99.2%

NYC L Line on-time performance

87%

Passenger satisfaction (was 78%)

8.3

GoA 3: Driverless Train Operation

GoA 3: The Rare Intermediate Step

- No driver in cab — ATO is fully responsible for train motion and station stops
- Attendant onboard for passenger safety, emergency response, and manual override
- Very limited deployment: cost nearly equal to GoA 4, but attendant eliminates labor savings
- Higher safety case complexity than GoA 2: redundant sensors, diverse computation, comprehensive fault detection
- Used mainly as a stepping stone on APMs (Automated People Movers) toward GoA 4

8.4

GoA 4: Unattended Train Operation

GoA 4: The Frontier of Automation

- No driver, no attendant — all motion, stopping, door, and emergency functions automated
- Highest engineering cost: redundancy at multiple levels, SIL 4 safety rigor, exhaustive validation
- Lowest operational labor cost — savings often justify capital over 25–40 year system life
- Paris Métro Line 14 (1998): first modern GoA 4 metro; since followed by Copenhagen, Singapore, Dubai
- Requires platform screen doors, advanced obstacle detection (LIDAR/radar), and automated evacuation protocols

GoA 4 Prerequisites

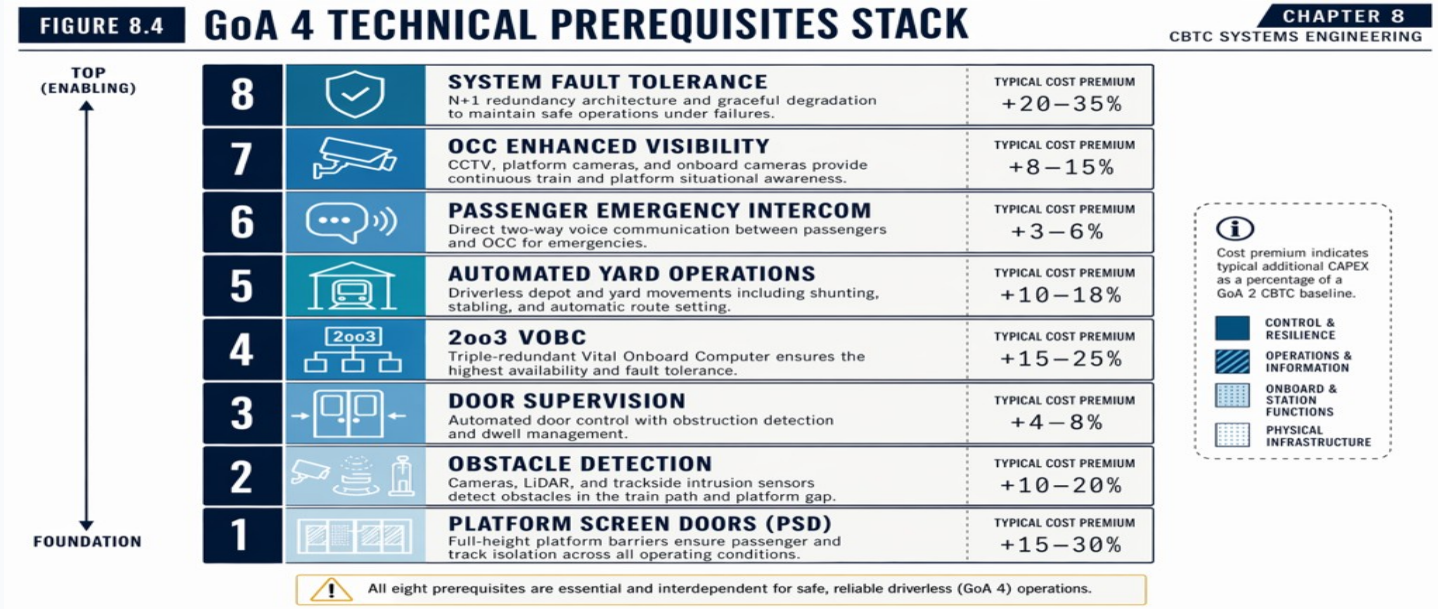

Figure 8.4 — Technical, safety, and infrastructure prerequisites for unattended train operation.

GoA Adoption: US vs. International

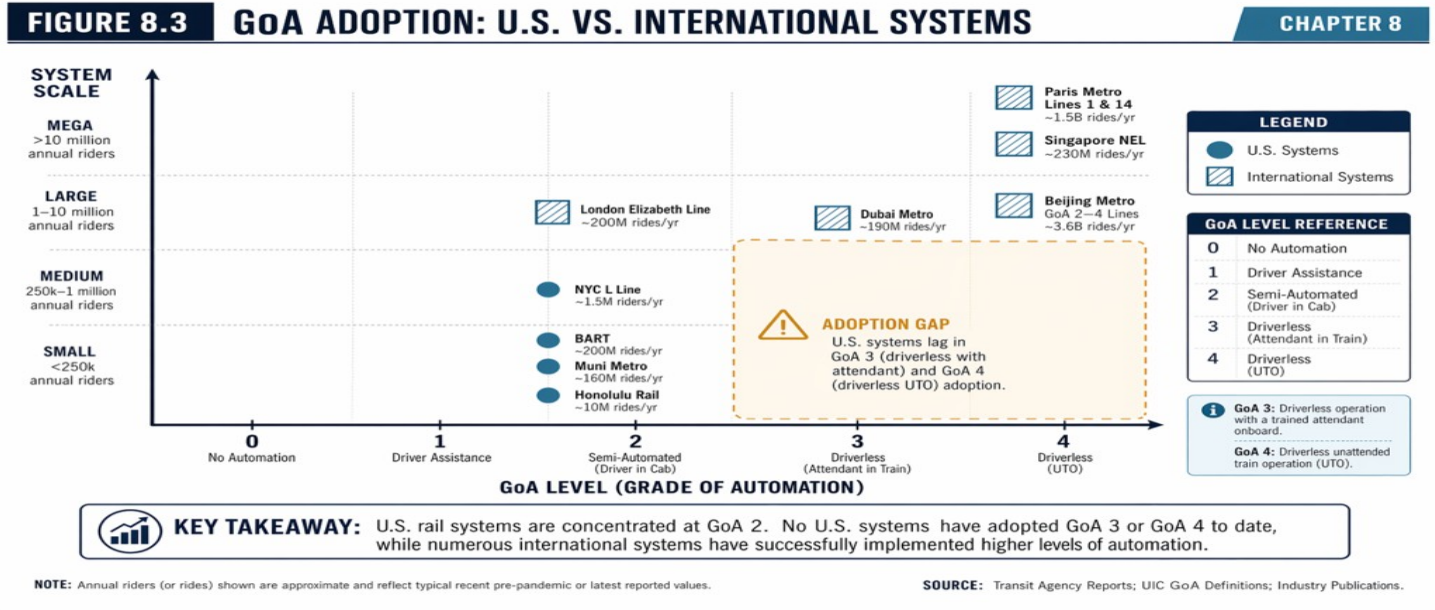

Figure 8.3 — North America lags Europe and Asia in GoA 3–4 adoption due to labor, regulatory, and cost factors.

US GoA 4 Deployments

- JFK AirTrain (2003): Bombardier CITYFLO 350, 8.2 km, fully GoA 4
- Honolulu Skyline (2023): GoA 4 automated people mover
- Denver A-Line: hybrid GoA 4 segments
- Las Vegas Monorail: partially GoA 4

- US barriers to GoA 4: strong labor unions, risk-averse procurement
- Regulatory fragmentation: FRA (commuter) vs. FTA (metro) oversight
- Cost-benefit: high capital cost, long payback in lower-wage regions
- Existing infrastructure: retrofit to GoA 4 dwarfs labor savings

8.5

Choosing the Right GoA for Your System

GoA Decision Flowchart

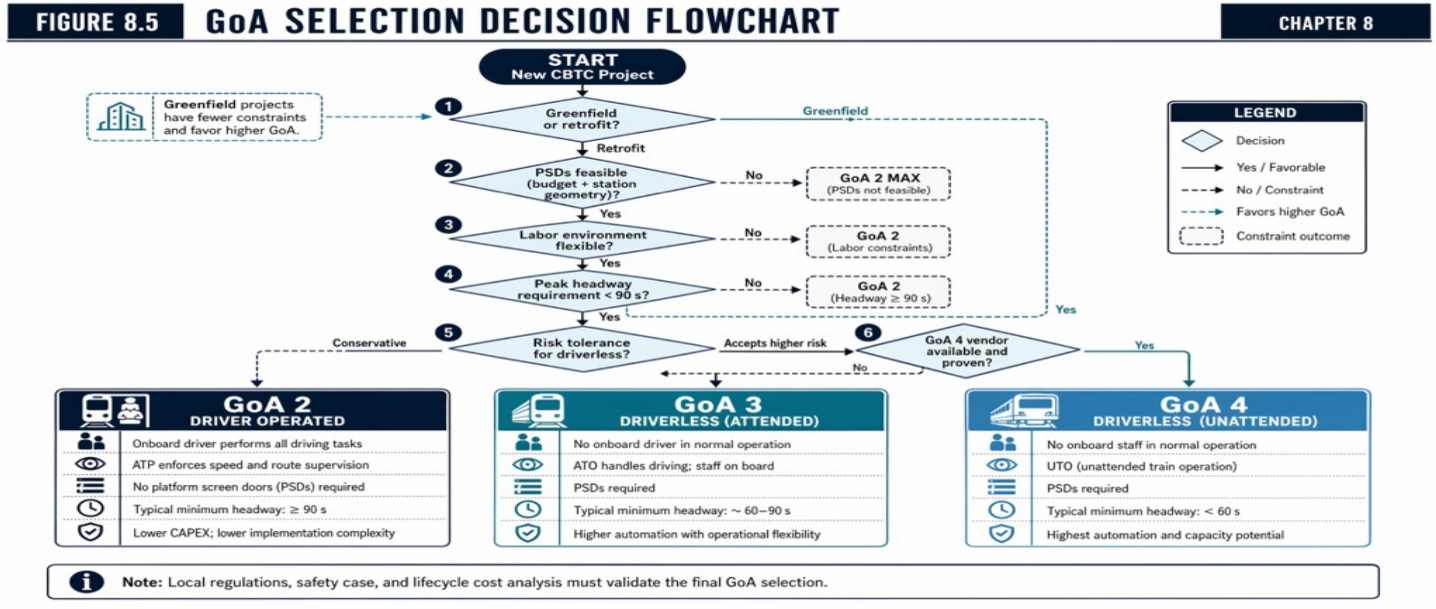

Figure 8.5 — Decision framework integrating labor, regulation, finance, and technical readiness.

GoA Selection Decision Factors

- Labor environment: union agreements, workforce transition plans, attrition-based staff reduction
- Regulatory readiness: existing frameworks for GoA 2 vs. new pathways needed for GoA 3–4
- Capital vs. operating cost: GoA 4 saves labor but adds platform doors, obstacle detection, safety case complexity
- New-build vs. retrofit: new systems (Honolulu) are more economical for GoA 4; legacy retrofits favor GoA 2
- Phased strategy: start at GoA 2, validate ATO for 2–3 years, then evaluate upgrade to GoA 3 or 4

Phased GoA Implementation Roadmap

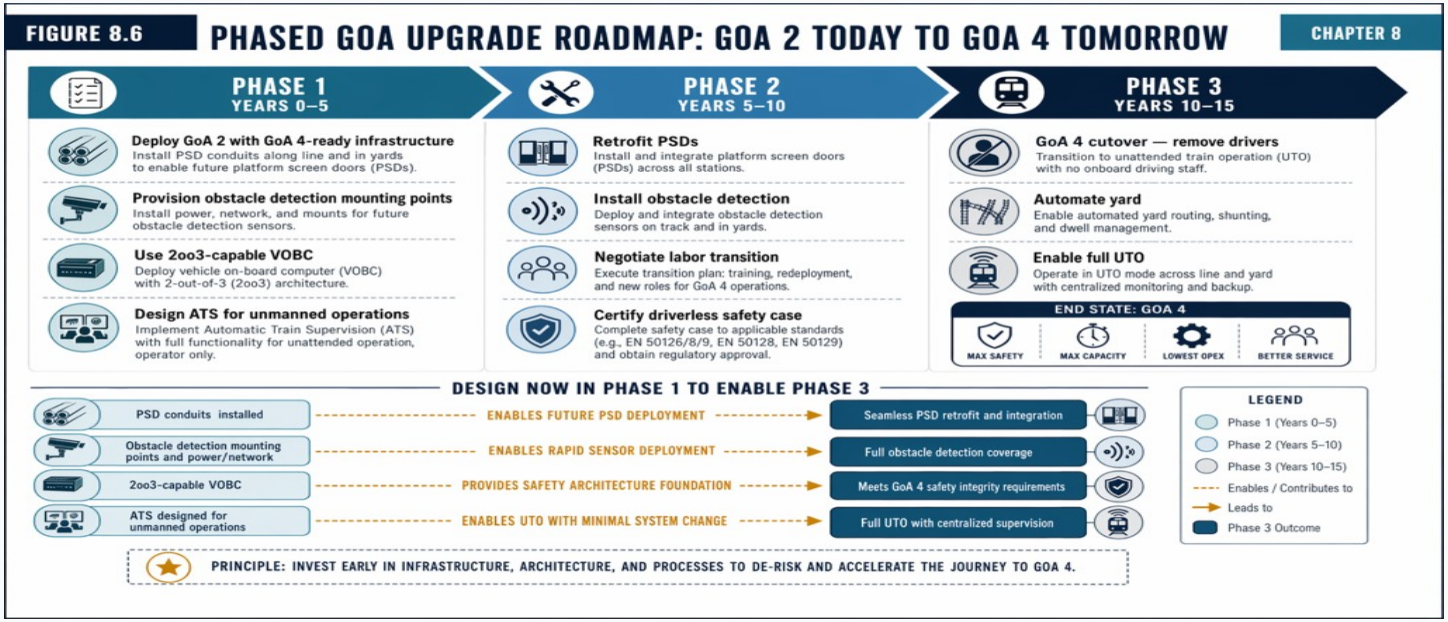

Figure 8.6 — Multi-decade roadmap: GoA 2 baseline → GoA 3 interim → GoA 4 target for new-build metros.

Key Takeaways

1. GoA is a responsibility allocation framework (IEC 62290-1), not a technology choice — CBTC enables higher GoA but is not synonymous with it
1. GoA 2 dominates US transit CBTC: preserves operator role, uses proven regulatory frameworks, avoids platform door costs
1. GoA 4 offers lowest lifecycle labor cost but requires highest capital investment, safety rigor, and platform infrastructure
1. US adoption of GoA 3–4 lags international peers due to labor agreements, regulatory fragmentation, and retrofit economics
1. Phased GoA strategy (2 → 3 → 4) reduces technical and organizational risk while building toward full automation

End of Chapter 8

Next: **Chapter 9: Operating Modes and Mode Transitions**

Questions & Discussion