Volume 2

CHAPTER 12

Project Lifecycle — From Planning to Revenue Service

Communications-Based Train Control
A Comprehensive Guide for US Transit Professionals
Francisco Wang

Chapter Overview

- The operational manual for agencies navigating feasibility through revenue service cutover
- Six sections mirror a real project timeline: Feasibility → Procurement → Systems Engineering → Safety → Testing → Cutover
- A CBTC project fails or succeeds based on lifecycle integrity — not vendor brilliance
- Typical brownfield project: $50–200M, 15–25 years, millions of person-hours
- Thesis: disciplined governance beats state-of-the-art equipment compromised by weak execution

CBTC Project Lifecycle Roadmap

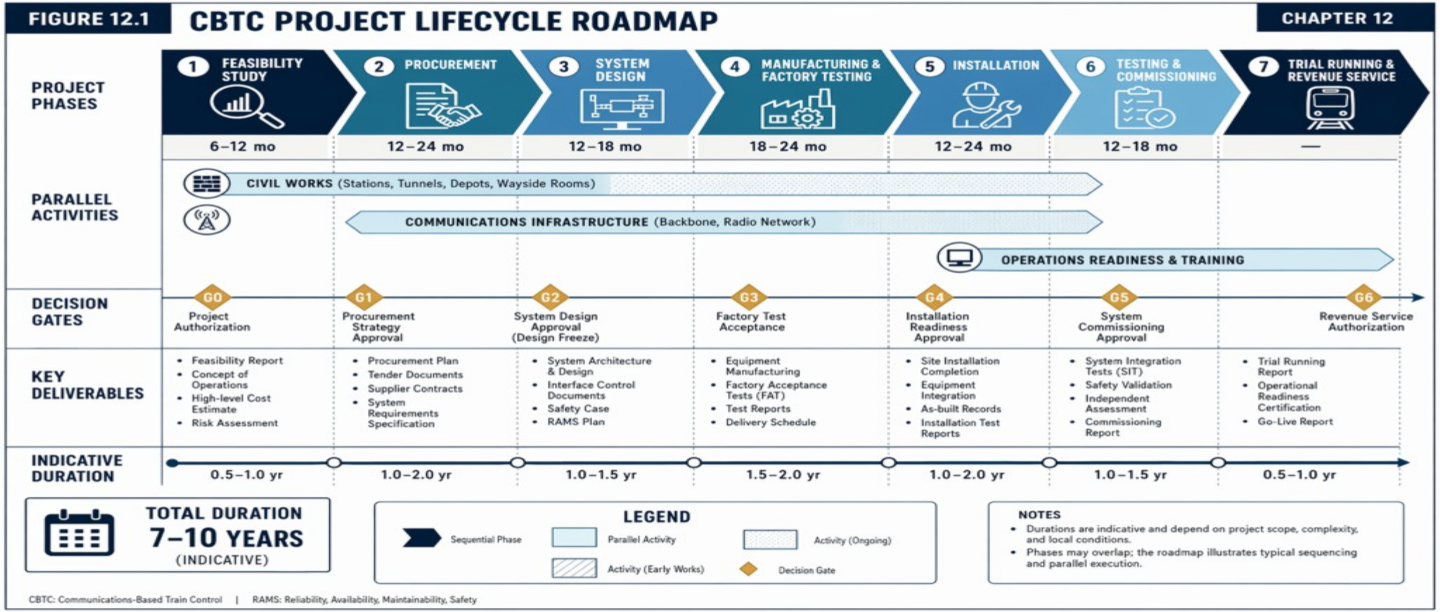

Figure 12.1 — CBTC Project Lifecycle Roadmap from feasibility through revenue service.

12.1

Feasibility Study and Business Case

Feasibility: Scope Trade-Offs

- Overlay vs. Replacement: overlay preserves fallback but costs more; replacement is cleaner but riskier
- Pilot Segment vs. Full-Line: pilot reduces schedule risk but delays benefits
- Bundled vs. Unbundled: bundled reduces interface risk; unbundled offers modularity

- FTA BCA methodology: 7% discount rate over 30 years
- CBTC delivers 15–40% capacity increase, 15–25% reliability improvement
- Capacity-induced ridership: L Line ridership grew 7% in first 2 years
- Business case: 4–8 months, $150–400K — smallest investment preventing largest overruns

Feasibility Pitfalls

- Underestimating brownfield complexity — budget 15–25% premium for legacy discovery and rework
- Ignoring cutover logistics — CBTC headway gains require bundled investments (PSDs, power, vehicles)
- Inadequate labor engagement — labor agreements are non-technical but often project-determining
- Rushed feasibility to meet political timelines → scope creep, rework, missed ridership targets

12.2

Procurement Strategies

Delivery Method Comparison

Criterion	DBB	Design-Build	PDB	P3
Schedule	Slowest	Fast (overlap)	Moderate–Fast	Slowest start
Cost Certainty	Low	Medium–High	High (Phase 2 fixed)	Fixed
Owner Control	High	Low	Medium	Very Low
US Precedent	Declining (MTA)	Preferred (BART)	Growing (HART)	Rare

Procurement Key Insights

- Modern US CBTC favors Design-Build for speed and single-point accountability
- Performance-based specs (IEEE 1474.1) encourage vendor competition vs. prescriptive specs
- Buy America: 70% domestic content (FY2024+), 90% iron/steel per BABA — limits competition to Siemens and few others
- Best-value RFP scoring: Technical 40–50%, Experience 20–25%, Management 15–20%, Price 20–30%
- Fixed-price DB with 2–3 year performance guarantees and 3–5% retention is standard

12.3

Systems Engineering and V-Model Development

V-Model Testing Framework

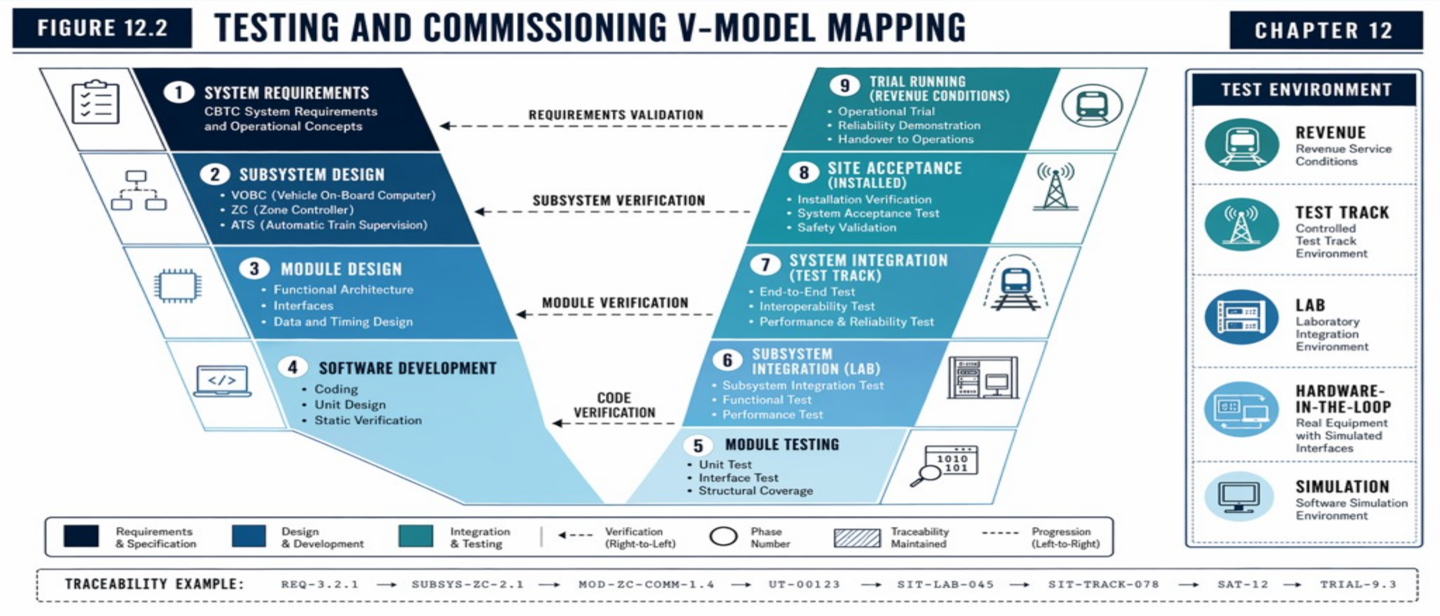

Figure 12.2 — V-Model lifecycle: requirements (left) linked to verification (right).

Systems Engineering Discipline

- 500–1,500 system-level requirements; 5,000–15,000+ at all levels — tool support mandatory (DOORS, Jama, Polarion)
- Bidirectional traceability: every requirement linked to tests and back; poor traceability → missing coverage
- Interface Control Documents (ICDs) define subsystem boundaries — lack of clear ICDs is a top integration failure source
- Configuration Management: software, hardware, AND site-specific data — route data CM failures cause late-stage delays
- Owner typically engages PMC from WSP, AECOM, HNTB, STV, or Jacobs for SE oversight

Requirements Traceability

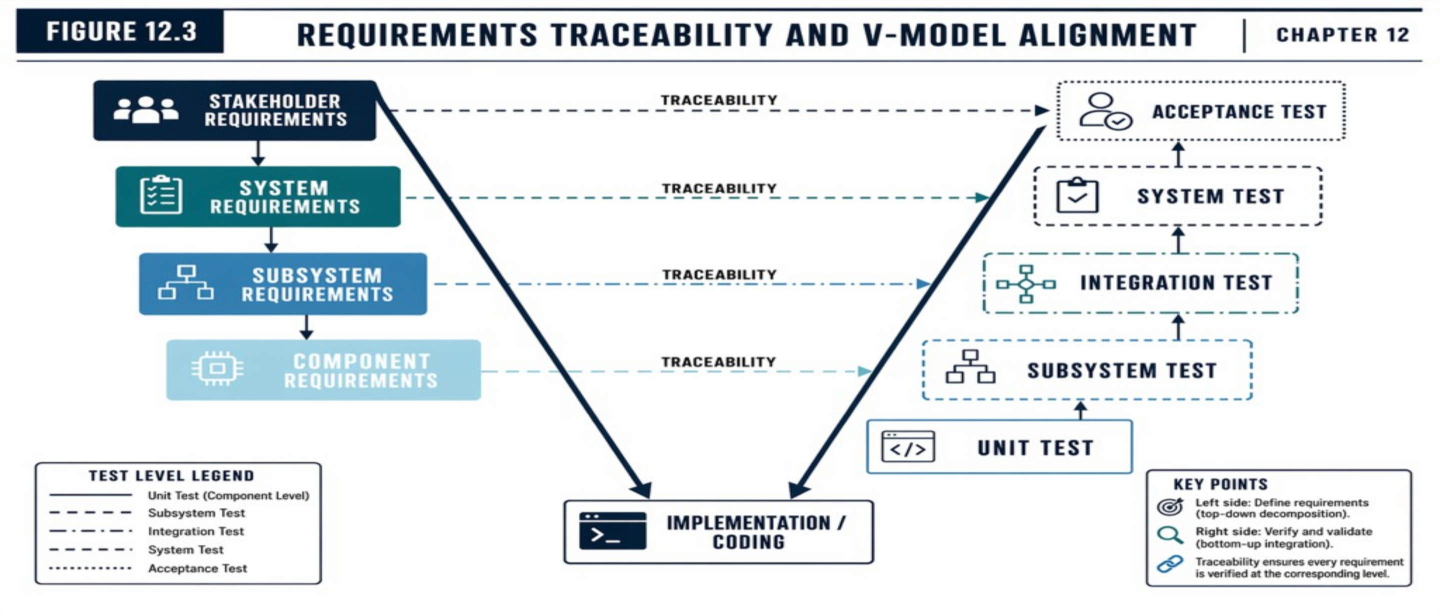

Figure 12.3 — Requirements Traceability and V-Model Alignment.

12.4

Safety Assurance and Independent Safety Assessment

Safety Case and ISA

- Safety case evolves: Preliminary (generic) → Applicable (site-specific) → Operational
- Multi-technique hazard analysis: PHA, SHA, FMEA, FTA, HAZOP, O&SHA
- SIL 4 (THR ≤ 10^{-9}/hour) for vital CBTC functions — ATP, MA, position validation

- ISA must be contractually, technically, and behaviorally independent — hired by Owner, not vendor
- ISA cost: 0.5–1.5% of CBTC contract; 60% effort during design phases
- US regulatory oversight is fragmented: SSO, agency SCB, NTSB, FRA (shared-use rail)
- Late-started safety work is the #1 cause of safety-case failure

Safety Case Structure

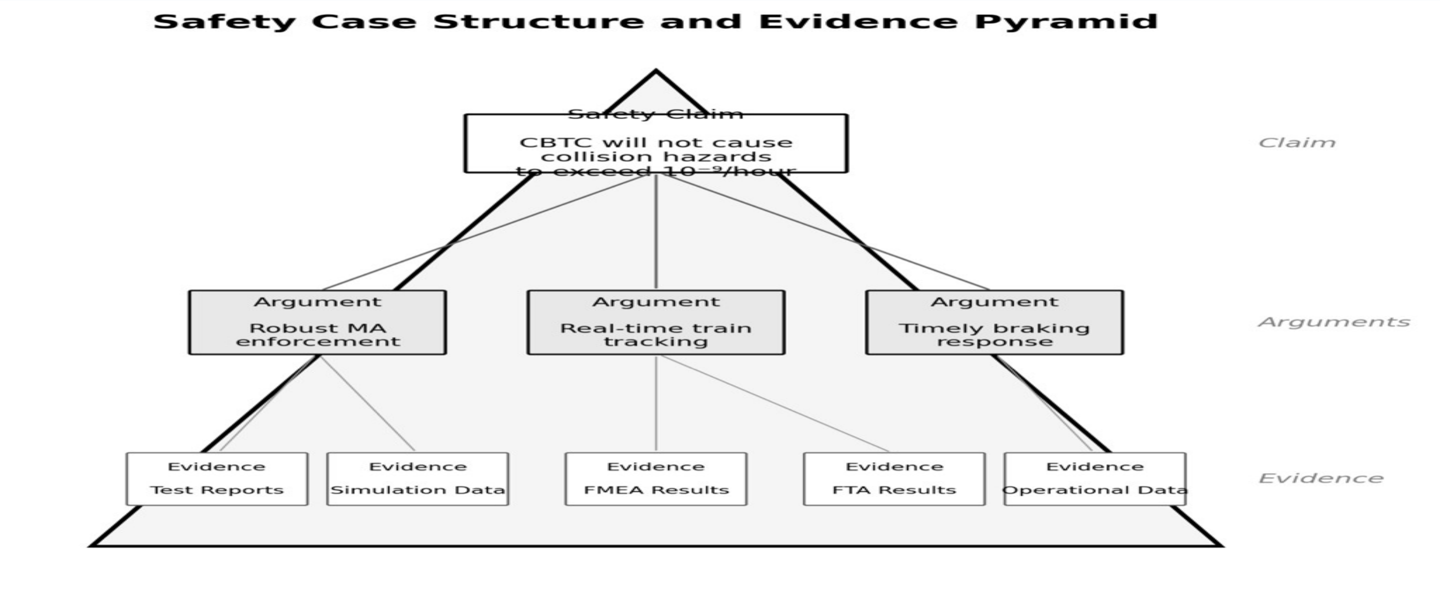

Figure 12.4 — Safety Case Structure and Evidence Pyramid.

12.5

Testing and Commissioning

Testing Phases: FAT → Shadow → Revenue

- FAT (6–12 weeks): Vendor lab, 60–90% functional coverage — validates baseline against spec
- SIT (12–20 weekends): On-site, non-revenue hours — replaces lab simulators with real hardware
- Dynamic Testing (4–8 weeks): First actual train movements under CBTC control — scenario progressions
- Shadow Running (6–12 months): CBTC monitors live traffic without control — evidence at operational scale
- Revenue Service Demonstration (2–4 weeks): CBTC with passengers, limited service — catches last-minute issues

Testing & Commissioning Timeline

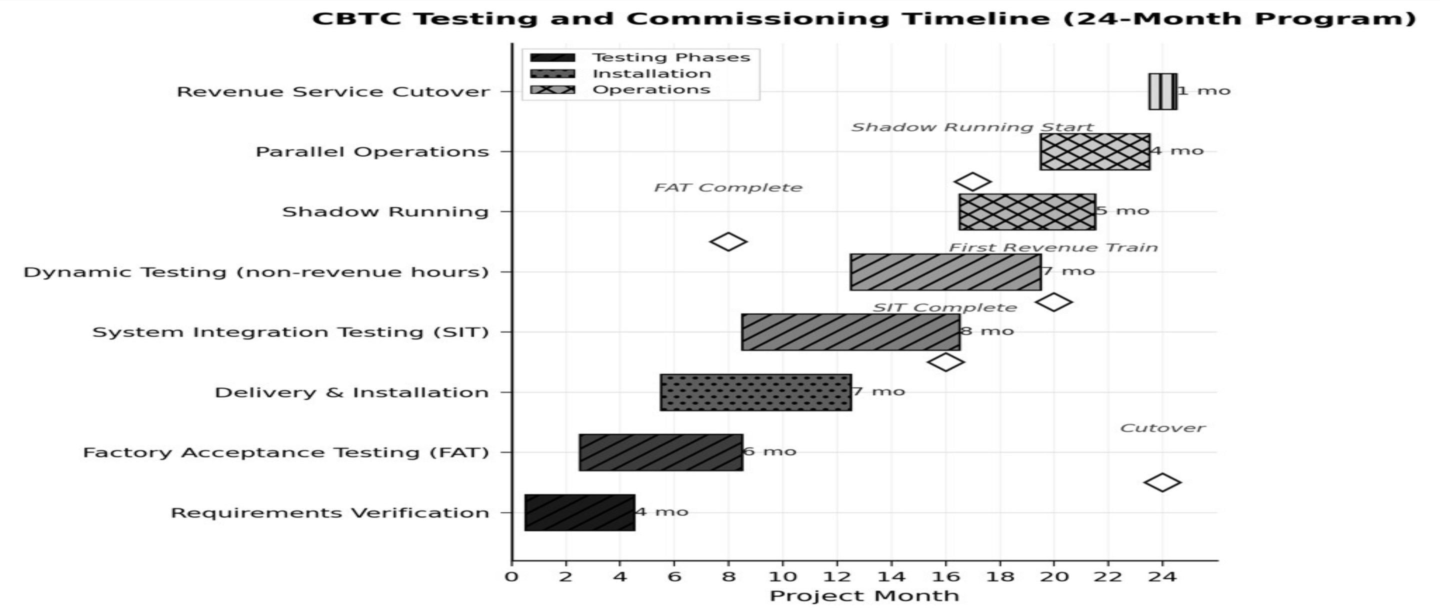

Figure 12.5 — Testing and Commissioning timeline from FAT through revenue service.

Test Environment Hierarchy

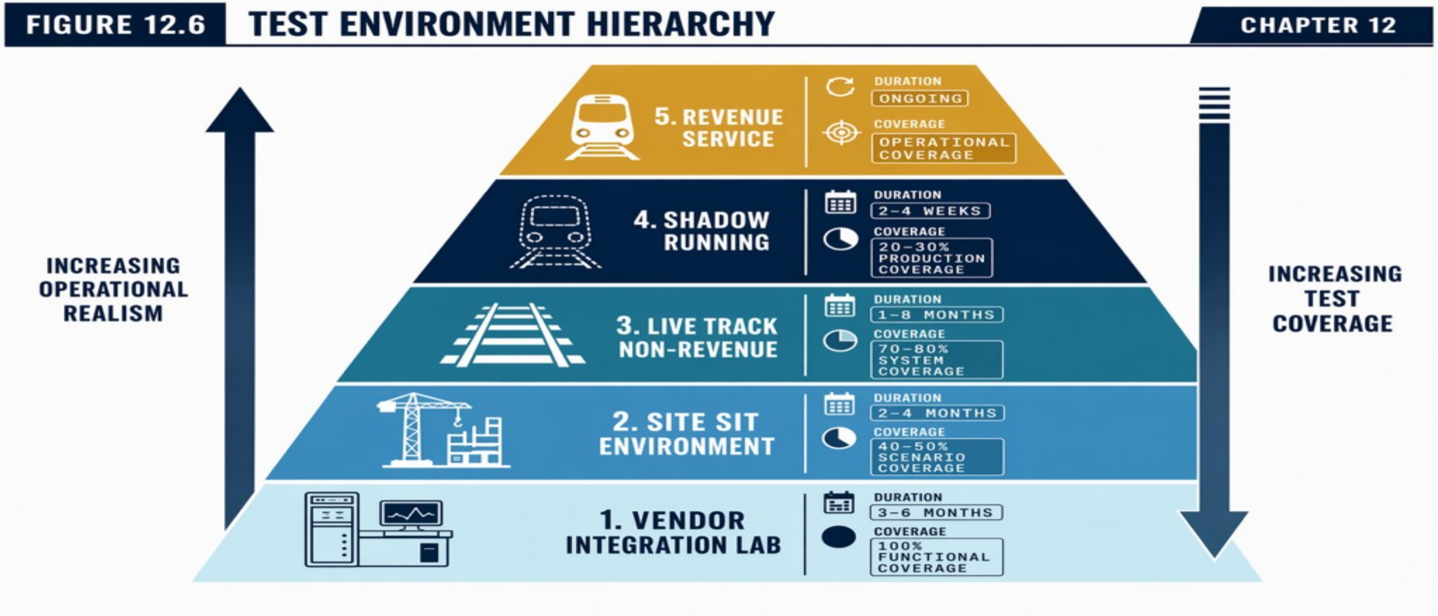

Figure 12.6 — Test environment hierarchy from lab simulation to live track.

12.6

Cutover Strategies — Big Bang vs. Phased Migration

Cutover Strategy Decision Matrix

Strategy	Best For	Mixed-Mode	Rollback Risk	US Examples
Big Bang	Greenfield	None	Moderate–High	Honolulu HART
Segment-Phased	Urban brownfield	6–12 months	Low	NYC L Line, 7 Line
Fleet-Phased	Large fleet retrofit	18–36 months	Moderate	BART TCMP
Function-Phased	Future GoA roadmap	0–24+ months	Low (per phase)	BART TCMP

Cutover Execution Essentials

- Method of Procedure (MOP): 60–100 page minute-by-minute choreography — 15-page MOPs give false confidence
- Full cutover rehearsal 4–6 weeks before actual event — replicates procedures, staff, equipment, timeline
- War room governance: system lead, ops lead, safety lead, vendor rep, interlocking specialist, comms coordinator
- Pre-defined rollback criteria: SIL 4 violation, >10% zone controller communication loss, safety case failure
- First 30–90 days: burn-in operations — reduced schedule, staged train introduction, rapid RCA feedback loop

Key Takeaways

1. Feasibility study ($150–400K, 4–8 months) is the smallest investment preventing the largest overruns — evaluate overlay vs. replacement, bundled vs. unbundled

1. Design-Build is now dominant for US CBTC procurement; Buy America limits vendor competition; Progressive DB is emerging

1. Disciplined SE with bidirectional traceability, V&V planning, and site-data CM is non-negotiable — poor SE cascades through all subsequent phases

1. Testing consumes 25–35% of project schedule; shadow running for 6–12 months before revenue cutover is the best predictor of stable operations

1. The cutover is the highest-risk event — phased approaches dominate US brownfield; MOP, rehearsal, and safety-first governance are essential

End of Chapter 12

Next: **Chapter 13: Performance Criteria and Capacity Analysis**

Questions & Discussion