# Operational TCO & Scale Impact Analysis – Runtime Cost, Ledger Load & Audit Overhead Model

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Scope: Total Cost of Ownership (TCO), capsule volume benchmarks, audit scaling and performance tolerance for MaxOneOpen v4.1

## 0. Purpose & CTO Cost Transparency Requirement

This document defines the operational expenditure model, performance envelope, and scaling stress impact of MaxOneOpen v4.1 deployments. It addresses runtime capsule load, ledger growth, audit response time, add-on cost boundaries and total cost of ownership (TCO) projections. It is mandatory for sovereign CTO-level deployments and required to assess economic feasibility and audit integrity under scale.

## 1. Capsule Volume Projections & Ledger Impact

Estimated capsule emission per system type (per 1000 operations):  
- Execution Control: 1000–1200  
- Audit & Trace: 800–1100  
- Policy/Rule Changes: 50–100  
- Fork / Recovery Events: 20–50  
- Add-on Systems: 300–600 (sandboxed)  
Ledger size growth estimate:  
- Capsule metadata chain only: ~100MB per 100K events  
- Full capsule state chain: ~1.2–2.5GB per 100K events (depending on payload class)

## 2. Audit Trace Overhead & Runtime Verification Cost

Average overhead for audit replay and forensic capsule reentry:  
- Execution sessions (10 steps): 5–10 ms overhead per query  
- Deep forensic chain replay (100–200 capsules): 100–200 ms  
- Real-time validation of ongoing execution: ~1–2% CPU baseline per node  
Performance cost per node is minimal under 10K daily capsules; scale considerations apply beyond that.

## 3. Add-on Cost Envelope & Governance Overhead

Add-on systems consume additional capsule and audit capacity:  
- Sandbox execution (Module 07): 15–25% runtime footprint increase  
- Add-on ledger binding: 10–15% capsule load growth  
- Governance/Audit capsule export cost: 0.2–0.5GB per month (per sovereign role)  
High audit tiers require additional disk and compute provisioning.

## 4. Deployment Cost Factors & TCO Reference

TCO calculation for a typical sovereign node (12-month cycle):  
- Capsule runtime framework: 1x standard containerized VM  
- Ledger storage (SSD): 1–3TB per year @ 50K–200K events/month  
- Audit infrastructure (optional): 1x forensic node per 5 sovereigns  
- Operational cost: ~15–30€ / sovereign / month (excluding hosting)  
Expected audit-proof cost remains below that of commercial governance stacks.

## 5. Certification Binding & Audit Transparency

This cost and scale analysis must be referenced in any deployment claiming sovereign auditability or CTO-grade certification. It supports certification decisions in Module 17 and operational validation in Module 15. Absence of this report invalidates scale-trace and system sustainability claims.