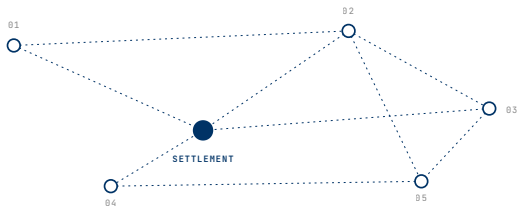
— A FRAMEWORK FOR MULTI-AUTHORITY MOBILITY ECOSYSTEMS

Governance-First Architecture for Federated Mobility Systems

Designing Neutral Settlement Infrastructure for Multi-Authority Transport Systems



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Contents

01 Executive Summary: The Sovereignty Challenge in Converged Mobility 03

02 Mobility Systems: Evolution & Institutional Reality 04

03 Multi-Authority Mobility Model 04

04 Orchestration vs. Authority: The Control Paradox 06

05 Financial Coordination & Settlement Shift 06

06 Institutional Failure Patterns 08

07 Governance-First Architecture 09

08 Centralized vs. Federated: An Architectural Comparison 11

09 Platform Implementation Stack 12

10 Evidence from the Field: Three Implementations 13

11 Governance in Practice: Principles from Real-World Systems 16

12 Future Mobility Infrastructure 17

13 Conclusion: The Mandate for a Federated Future 18

– About the Author 18

– Appendix: Glossary 18

01 — Executive Summary: The Sovereignty Challenge in Converged Mobility

This paper is written for transport authorities, regulators, and platform architects responsible for designing or governing multi-authority mobility ecosystems.

A typical mobility journey spans multiple services — toll roads, urban transit, parking, and emerging systems such as EV charging. While the experience appears unified to the traveler, each segment is governed by a different authority with its own pricing policies, regulatory frameworks, and revenue systems.

This is not a connectivity problem. It is a governance problem. Mobility interoperability is constrained not by the inability of systems to communicate, but by the institutional realities embedded within them. Tolling, road usage charging, and mobility services operate under distinct legal doctrines, financial models, and audit requirements — conditions that cannot be unified without creating ambiguity in authority, revenue ownership, and accountability.

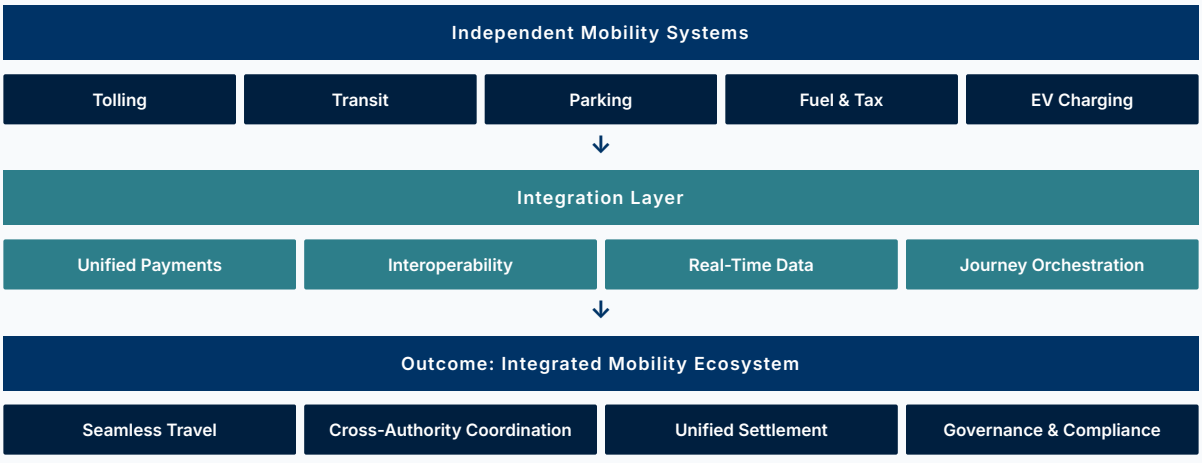
Centralized platform approaches attempt to resolve this by integrating coordination, execution, and financial flows within a single system. In multi-authority ecosystems, this creates structural conflict: platforms absorb decision rights that institutions must retain, producing resistance, fragmentation, and limited scalability. This paper introduces a Governance-First Architecture built on three interoperable layers:

- **Orchestration** — coordinates traveler interactions and service sequencing
- **Execution** — preserves authority control over pricing, validation, and policy
- **Settlement** — operates as neutral infrastructure for financial coordination, reconciliation, and auditability

This separation distinguishes coordination rights from decision rights. Orchestration enables a unified experience without controlling infrastructure systems. Settlement ensures that financial outcomes are consistent, traceable, and auditable — without centralizing ownership. By designing systems this way, mobility ecosystems can scale across jurisdictions and operators without altering institutional roles.

The paper provides a framework for transport authorities, regulators, and platform architects to design interoperable mobility ecosystems aligned with legal, financial, and governance realities.

FIG. 01 · CONVERGENCE OF MOBILITY SYSTEMS — 3 LAYERS · SECTION 01



Mobility infrastructure that has historically operated independently is increasingly converging into integrated ecosystems that support multimodal journeys.

02 — Mobility Systems: Evolution & Institutional Reality

Mobility systems have evolved from standalone, mode-specific services into coordinated journey experiences. Tolling, transit, parking, and related services now connect through digital interfaces that enable unified planning, access, and payment at the user level.

This convergence, however, is limited to the experience layer. Beneath it, mobility systems remain institutionally distributed — each service operating within its own regulatory framework, financial structure, and operational model under independent authorities. Integration at the interface does not alter these underlying constraints. The critical distinction is this: integrated mobility represents coordination, not unification, of independently governed systems.

From an institutional perspective, mobility ecosystems consist of participants with distinct and non-interchangeable roles:

- authorities maintaining pricing control and policy enforcement
- operators ensuring system reliability and compliance
- financial systems guaranteeing accuracy and settlement finality
- platforms optimizing coordination and user experience

These roles are structurally incompatible with centralized models as integration expands across jurisdictions.

A deeper constraint emerges from the legal and financial foundations of each service type. Tolling systems are tied to infrastructure assets with strict revenue traceability. Road usage charging is treated as a statutory levy under public finance rules. Mobility services operate within commercial and consumer protection frameworks. Combining these within a single operational or financial model creates ambiguity in legal authority, pricing control, and revenue allocation — introducing audit risk, regulatory conflict, and accountability gaps.

The evolution of mobility systems, therefore, reveals a consistent structural condition: user experience can converge, but institutional authority remains distributed. Scalable interoperability depends on designing systems that align with this distribution — enabling coordination across participants without consolidating control.

03 — Multi-Authority Mobility Model

A mobility journey — such as travel across toll roads, public transit, and urban parking — appears unified from the traveler's perspective. In practice, it is a sequence of independently governed operational events, each executed within a distinct infrastructure system under a specific authority. Each authority retains control over pricing, validation, revenue ownership, and policy enforcement — responsibilities that cannot be transferred without altering regulatory accountability and operational liability.

This leads to a fundamental structural separation: coordination spans services, while execution remains with the authorities. Mobility systems operate with two distinct rights — coordination rights, which enable service sequencing and a unified user experience, and decision rights, which remain with authorities over pricing, validation, and policy. A unified journey is therefore not executed by a single system, but coordinated across multiple authority-controlled systems, with each event independently governed, while orchestration ensures continuity.

FIG. 02 · MULTI-AUTHORITY MOBILITY JOURNEY

JOURNEY MODEL · SECTION 03

A JOURNEY SEQUENCE

B AUTHORITIES GOVERNING THE JOURNEY

C COORDINATED OUTCOMES

Modern mobility journeys frequently span multiple infrastructure systems operated by independent authorities.

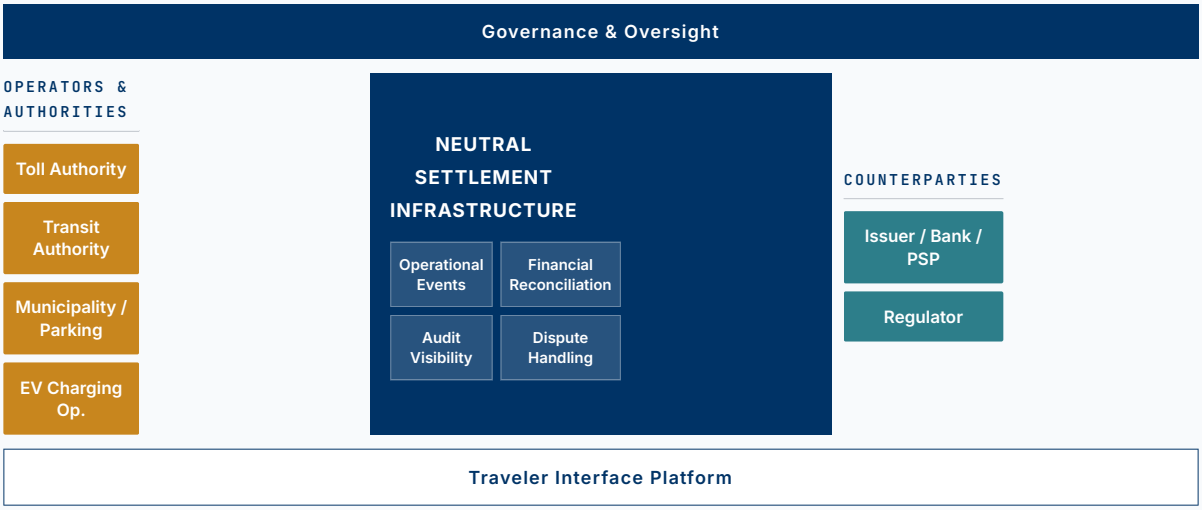
Beyond individual journeys, mobility ecosystems operate through structured interactions between multiple institutional participants:

- Platforms coordinate interactions and user experience
- Authorities execute services and enforce policy
- Financial systems ensure reconciliation and settlement
- Oversight functions maintain audit and compliance

These interactions do not form a centralized system — they constitute a federated model, where each participant operates within defined boundaries while contributing to a coordinated outcome.

FIG. 03 · INSTITUTIONAL INTERACTION MAP

FEDERATED MODEL · SECTION 03



Mobility systems operate through structured interactions between authorities, financial institutions, platforms, and oversight functions, coordinated through neutral settlement infrastructure while maintaining authority boundaries.

This establishes the operating condition for multi-authority mobility systems: interoperability is achieved through coordination across participants that do not share control. Scalable mobility ecosystems must therefore be designed as federated structures — where coordination overlays distributed execution, and institutional boundaries remain intact.

04 — Orchestration vs. Authority: The Control Paradox

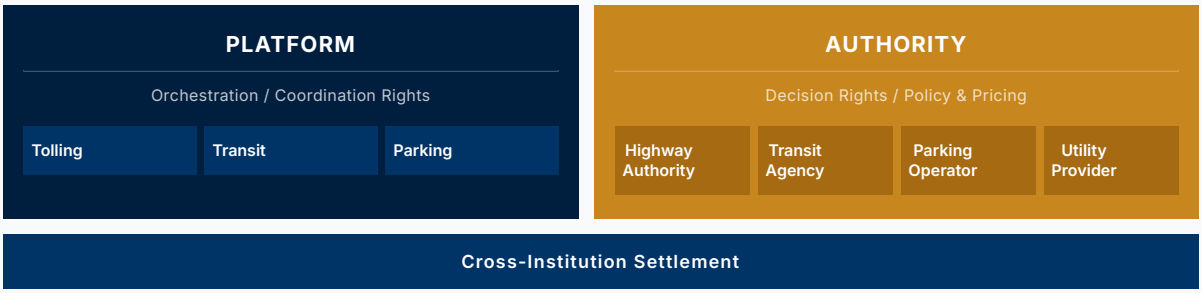
As mobility journeys span multiple systems, digital platforms play a central role in coordinating the traveler experience. Applications, vehicle interfaces, and payment aggregators enable users to plan, initiate, and complete journeys across services. However, coordination does not imply control.

Infrastructure systems remain governed by authorities that retain decision rights over pricing, validation, policy enforcement, and revenue collection — responsibilities tied to regulatory mandates and operational accountability that cannot be externalized without altering institutional roles. This creates a structural boundary: orchestration coordinates interactions, while execution determines outcomes. Orchestration sequences journeys, routes requests, and presents a unified interface. Execution enforces pricing logic, validates usage, and applies policy rules. Infrastructure systems, therefore, remain the source of operational and financial truth.

This separation gives rise to the control paradox: a system that appears unified at the experience layer is governed by multiple independent authorities that do not share control. Centralized architectures attempt to resolve this by combining coordination and execution within a single platform — absorbing decision rights that authorities must retain, and creating conflicts in pricing authority, revenue ownership, policy enforcement, and accountability that limit scalability across jurisdictions. A scalable mobility architecture must preserve this boundary. Coordination must operate across systems without assuming ownership of decision-making.

FIG. 04 · ORCHESTRATION VS AUTHORITY

CONTROL BOUNDARY · SECTION 04



Mobility platforms coordinate traveler experiences, while infrastructure authorities retain control over pricing, enforcement, and operational policy.

This boundary defines a core design condition for interoperability: a unified mobility experience must be delivered without centralizing control over infrastructure systems.

05 — Financial Coordination & Settlement Shift

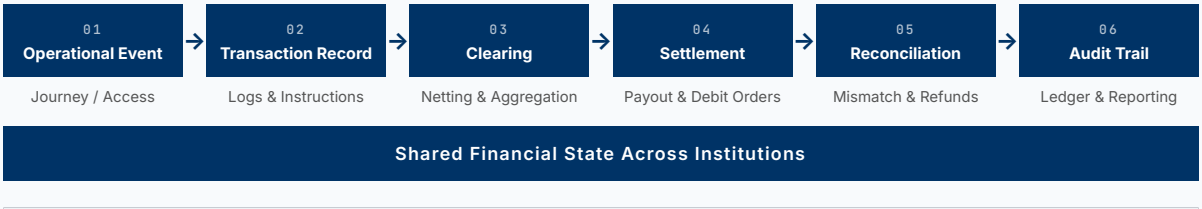
In traditional mobility systems, financial settlement operates as a back-office function. Transactions are recorded within individual systems and reconciled through periodic clearing cycles — a model that assumes limited interaction between systems and tolerates delayed consistency. As mobility journeys span multiple authorities, this assumption breaks down. A single journey generates multiple financial events across independently governed systems, and without a shared, consistent view of these events, discrepancies emerge in transaction records, revenue attribution, and settlement outcomes.

This requires a structural shift: settlement moves from post-processed reconciliation to event-linked financial coordination. In this context, settlement is not a payment routing function — it is the deterministic reconstruction of financial obligations between participants, derived from operational events and agreed rules. The financial functions that underpin this model are distinct:

- **Switching** routes transaction requests
- **Clearing** determines financial positions between parties
- **Settlement** executes fund transfers based on clearing outcomes
- **Reconciliation** ensures consistency of records
- **Dispute resolution** handles exceptions
- **Audit** ensures traceability and accountability

In multi-authority systems, these functions must operate on a shared representation of underlying events.

FIG. 05 · FINANCIAL LIFECYCLE — EVENT-LINKED · SECTION 05



End-to-end lifecycle from operational event to audit trail, ensuring consistency, traceability, and auditability across institutions.

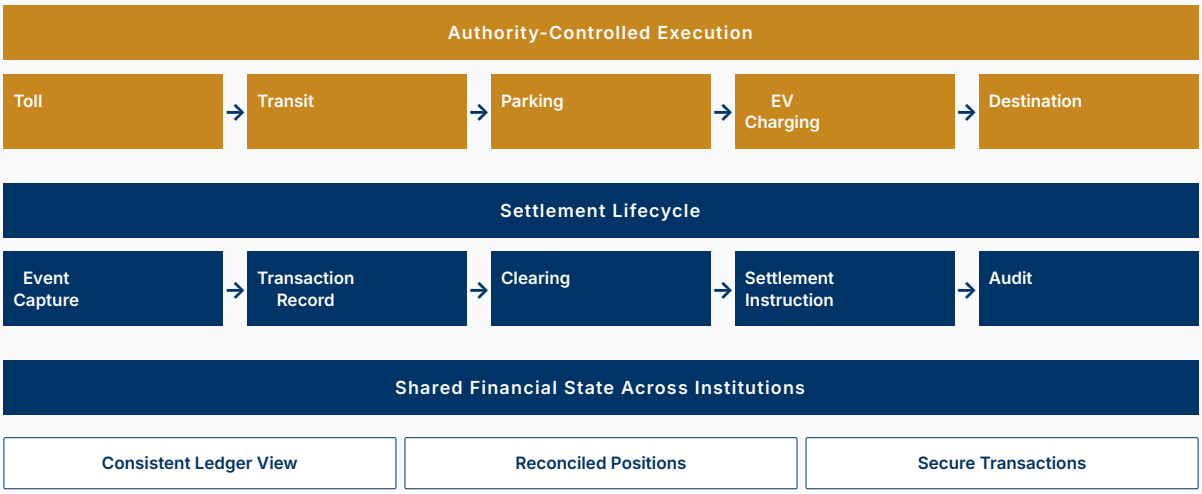
Each operational event — a toll passage, a transit entry — must generate a financial record consistently visible across participating systems, following a traceable lifecycle:

> Operational Event → Transaction Record → Clearing Logic → Settlement Instruction → Reconciliation & Exception Handling → Dispute Resolution → Audit Trail.

A critical requirement within this model is revenue segregation:

- Asset-based toll revenues are linked to infrastructure financing and concession structures
- Statutory charges such as road usage charging are governed by public finance and treasury controls
- Commercial mobility services are subject to contractual and market frameworks

Commingling these streams creates audit risk, regulatory conflict, and legal ambiguity — financial coordination mechanisms must therefore preserve clear attribution of revenue to its originating authority and legal context.



Settlement becomes governance infrastructure when financial outcomes are derived from shared, event-level lifecycle coordination across institutions. This establishes a shift in system design.

Settlement becomes part of the governance infrastructure — providing a neutral layer that ensures consistency, traceability, and auditability of financial outcomes across independently governed systems, without influencing pricing, policy, or execution. Interoperability at scale depends not only on coordinating operations, but on aligning financial outcomes across institutions through shared, event-linked settlement mechanisms.

06 — Institutional Failure Patterns

As mobility systems expand across multiple authorities, failures increasingly arise not from technology limitations, but from misalignment between system design and institutional structure. These failures occur when independently governed systems are expected to operate as a unified experience without a shared framework for financial coordination and accountability. Six recurring patterns emerge.

- **Fragmented Financial Reconciliation.** Each authority maintains its own transaction and revenue records. Without a shared event-level view, inconsistencies arise in transaction status, amounts, and settlement outcomes — leading to delays, manual intervention, and reduced confidence in financial accuracy.
- **Ambiguity in Dispute Ownership.** When inconsistencies occur — such as incorrect charges or failed validations — responsibility for resolution is often unclear, resulting in delayed handling, fragmented escalation, and diffuse accountability across participants.
- **Inconsistent Revenue Attribution.** In multi-segment journeys, allocating revenue across authorities becomes complex. Without transparent settlement logic, distribution may not reflect actual usage or agreed policies, creating financial misalignment and undermining institutional trust.
- **Limited Cross-System Visibility.** Operational events are recorded within individual systems but are not consistently visible across participants. Authorities cannot independently verify cross-system transactions, limit auditability, and increase reliance on intermediaries.
- **Unclear Customer and Refund Responsibility.** Customer-facing issues such as refunds or reversals do not map cleanly to a single system. Without a clear linkage between operational events and financial ownership, responsibility becomes fragmented and outcomes inconsistent.
- **Dependency on Central Intermediaries.** In the absence of structured coordination, centralized platforms assume responsibility for routing, reconciliation, and settlement interpretation. While this simplifies integration, it concentrates financial visibility and operational dependency within a single entity — potentially conflicting with institutional roles.

FIG. 07 · INSTITUTIONAL FAILURE PATTERNS

CAUSAL MATRIX · SECTION 06

Failure Condition	Operational Breakdown	Systemic Impact
Fragmented Settlement Systems	Inconsistent transaction records	Revenue Leakage
Data Silos Across Authorities	Reconciliation delays and mismatches	Compliance Gaps
Absence of Neutral Settlement Infrastructure	Dispute ownership ambiguity	Operational Inefficiency
		Inter-authority Friction

Root Cause: Lack of coordinated governance and shared settlement infrastructure

Fragmented settlement, siloed data, and the absence of neutral clearing infrastructure create systemic failures in mobility ecosystems.

These patterns share a consistent root cause: mobility systems are being integrated at the experience layer without aligning financial coordination and institutional accountability. Addressing them requires a structural approach that aligns system design with institutional boundaries — ensuring that coordination, execution, and financial outcomes operate within a shared and consistent framework.

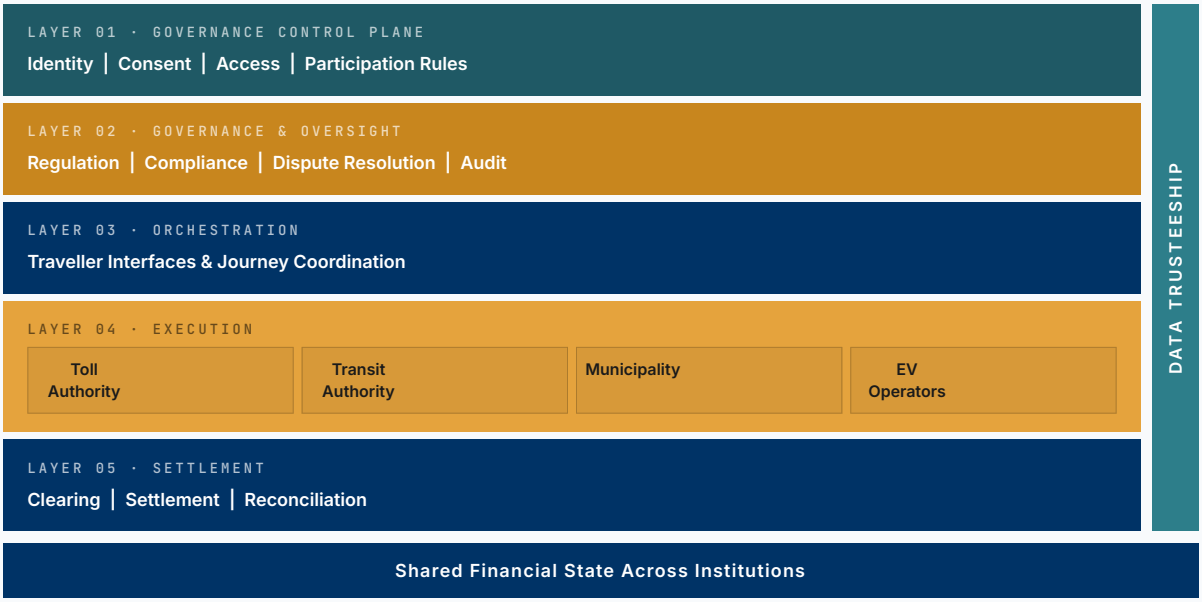
07 — Governance-First Architecture

Interoperability in multi-authority mobility systems depends on aligning system design with institutional responsibilities. This requires a structural separation between coordination, execution, and financial accountability — ensuring that systems can interoperate without consolidating control. The Governance-First Architecture establishes this separation through three interoperable layers.

- **The Orchestration Layer** coordinates the traveler journey across services — managing interaction sequencing, request routing, and user experience — without defining pricing, enforcing policies, or validating service usage.
- **The Execution Layer** represents infrastructure systems operated by authorities, including tolling, transit, and parking. Authorities retain decision rights over pricing, validation, policy enforcement, and operational control. This layer is the source of operational truth.
- **The Settlement Layer** provides a neutral mechanism for financial coordination — ensuring that transactions derived from operational events are consistently recorded, reconciled, and settled across participants. Settlement derives outcomes from shared events and agreed rules, without influencing pricing, policy, or execution.

This layered separation establishes a clear boundary condition: orchestration coordinates interactions without assuming control; execution enforces infrastructure policy within authority systems; settlement ensures financial consistency without centralizing ownership. Together, these layers enable interoperability while preserving institutional autonomy.

FIG. 08 · GOVERNANCE-FIRST ARCHITECTURE — 5 LAYERS · SECTION 07



The Governance-First architecture separates orchestration, infrastructure execution, and financial settlement, supported by a governance control plane and data trusteeship that operate across these layers.

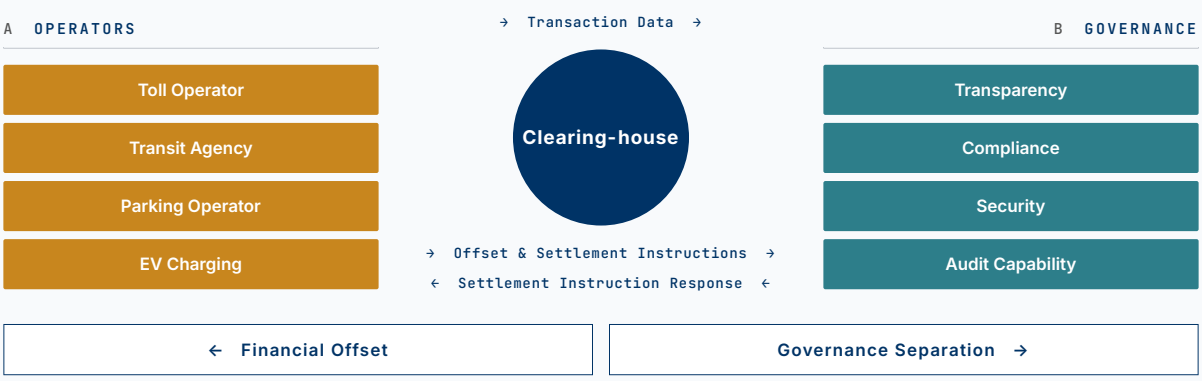
Multi-authority systems additionally require a governance control plane operating across all three layers. Its role is to manage:

- identity and participant recognition
- consent and access permissions
- policy metadata and rule distribution
- participation and interaction governance

It does not perform transaction processing, pricing, billing, or settlement — it does not hold funds or determine financial outcomes. Its primary function is to enable interoperability while preserving institutional boundaries.

Data is treated as a governed asset rather than a platform byproduct. Authorities retain trusteeship over operational events, financial records, and policy-relevant information generated within their domains. Access is governed through role-based controls and consent mechanisms — ensuring that data sharing enables coordination without transferring ownership, and that auditability, accountability, and compliance are maintained across the ecosystem.

FIG. 09 · INSTITUTIONAL SEPARATION — CLEARINGHOUSE · SECTION 07



Institutional coordination is achieved by preserving authority control over execution, enabling orchestration without ownership, and establishing settlement as neutral shared infrastructure.

The architecture is defined by three operating principles:

- **Unified Orchestration** limits platform scope to coordination
- **Federated Execution** preserves authority control over infrastructure
- **Neutral Settlement Infrastructure** ensures consistent financial outcomes across participants

Together, they enable ecosystem-scale interoperability without increasing governance friction. Coordination is enabled across systems, while control remains distributed across institutions.

08 — Centralized vs. Federated: An Architectural Comparison

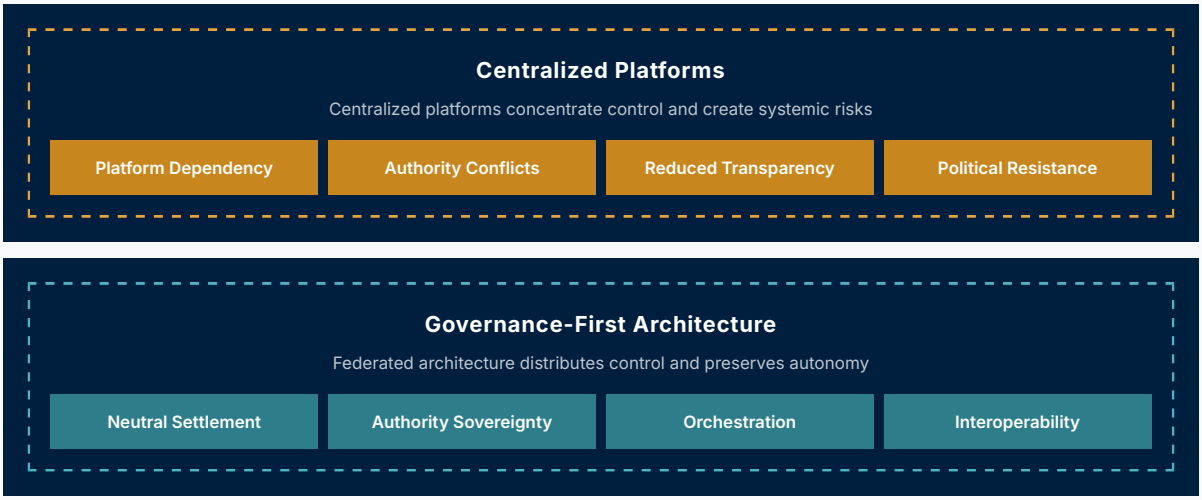
Mobility systems can be structured using different architectural approaches depending on the governance context and scale. Two dominant models emerge: centralized platform architectures and governance-first, federated architectures.

Centralized platforms integrate user experience, infrastructure logic, and financial flows within a single system. This model can simplify implementation in environments governed by a single authority or within tightly controlled deployments, enabling faster rollout and lower initial integration complexity. However, as systems expand across multiple independent authorities, centralized models encounter structural limitations. Integrating pricing logic, operational rules, and financial flows into a single platform introduces dependencies that conflict with institutional responsibilities — absorbing decision rights that authorities must retain, creating ambiguity in legal authority, weakening audit boundaries, and introducing regulatory risk. As a result, such models face resistance and struggle to scale across jurisdictions.

Governance-First Architecture addresses these constraints by separating coordination, execution, and financial settlement into interoperable layers — enabling systems to scale across authorities without consolidating control, and aligning system design with institutional structure.

FEATURE	CENTRALIZED PLATFORM	GOVERNANCE-FIRST ARCHITECTURE
Control	Platform-centric	Authority-sovereign
Scalability	Fast initial deployment, limited multi-authority scale	Moderate onboarding, scalable across ecosystems
Revenue Risk	Concentrated within the platform	Distributed across authorities
Interoperability	Proprietary integration	Federated coordination
Regulatory Alignment	Challenging across jurisdictions	Preserved by design
Implementation Complexity	Low initially, increases with scale.	Requires upfront stakeholder alignment across institutions, stable once established
Time to Value	Fast in controlled environments	Slower onboarding and higher upfront governance design investment, but durable outcomes at scale
Customer Ownership	Concentrated in platform	Distributed across participants

FIG. 10 · CENTRALIZED VS GOVERNANCE-FIRST ARCHITECTURE PARALLEL COMPARISON · SECTION 08



Centralized mobility platforms concentrate institutional authority, while Governance-First architecture distributes responsibilities across independent participants.

The choice between these approaches depends on the institutional context. Centralized architectures are effective in controlled environments, while governance-first models provide a more sustainable foundation for multi-authority ecosystems.

09 — Platform Implementation Stack

The implementation stack maps directly to the three-layer separation established in Section 7, translating governance-first principles into operational systems without collapsing institutional boundaries or redistributing control.

- **Orchestration Layer (Coordination Systems)** manages user interaction and journey coordination across services, encompassing journey planning and service sequencing, request routing across authority systems, unified user interface and access management, and multi-system session management. This layer coordinates interactions but does not define pricing, enforce policy, or validate service usage.
- **Execution Layer (Authority Systems Integration)** represents integration with infrastructure systems operated by authorities, covering service validation such as toll passage and transit entry, pricing application based on local policy, policy enforcement and rule execution, and operational event generation. This layer preserves authority ownership of operational logic and decision-making.
- **Settlement Layer (Financial Coordination Systems)** provides shared infrastructure for financial consistency across participants, handling event-linked transaction recording, clearing logic based on agreed rules, settlement instruction generation, reconciliation and exception handling, and dispute tracking and audit support. This layer ensures that financial outcomes remain consistent, traceable, and auditable across systems without centralizing revenue ownership.
- **Governance Control Plane (Cross-Layer Enablement)** operates across all layers to manage identity and participant registry, consent and access control, policy metadata and rule distribution, and interaction governance and onboarding. It does not perform execution, pricing, or settlement functions, but enables controlled interoperability across participants.

FIG. 14 · PLATFORM IMPLEMENTATION STACK — 6 LAYERS · SECTION 09

Technology platforms implement Governance-First architecture while infrastructure authorities retain operational control of infrastructure systems.

Implementation must additionally address three cross-cutting requirements:

- **Interoperability Standards** — common data models and event definitions to ensure consistency across systems
- **Auditability** — end-to-end traceability from operational event to financial outcome
- **Scalability** — the ability to onboard new authorities and services without structural changes

These requirements ensure system stability as participation expands. Coordination is standardized, execution remains distributed, and financial outcomes are consistently aligned across participants.

10 — Evidence from the Field: Three Implementations

Real-world mobility systems demonstrate that interoperability succeeds when coordination is enabled without consolidating institutional control. The following cases illustrate how different ecosystems have addressed — or struggled with — the balance between orchestration, execution, and financial settlement.

CASE 01 · INDIA FASTag: Interoperable Tolling at National Scale

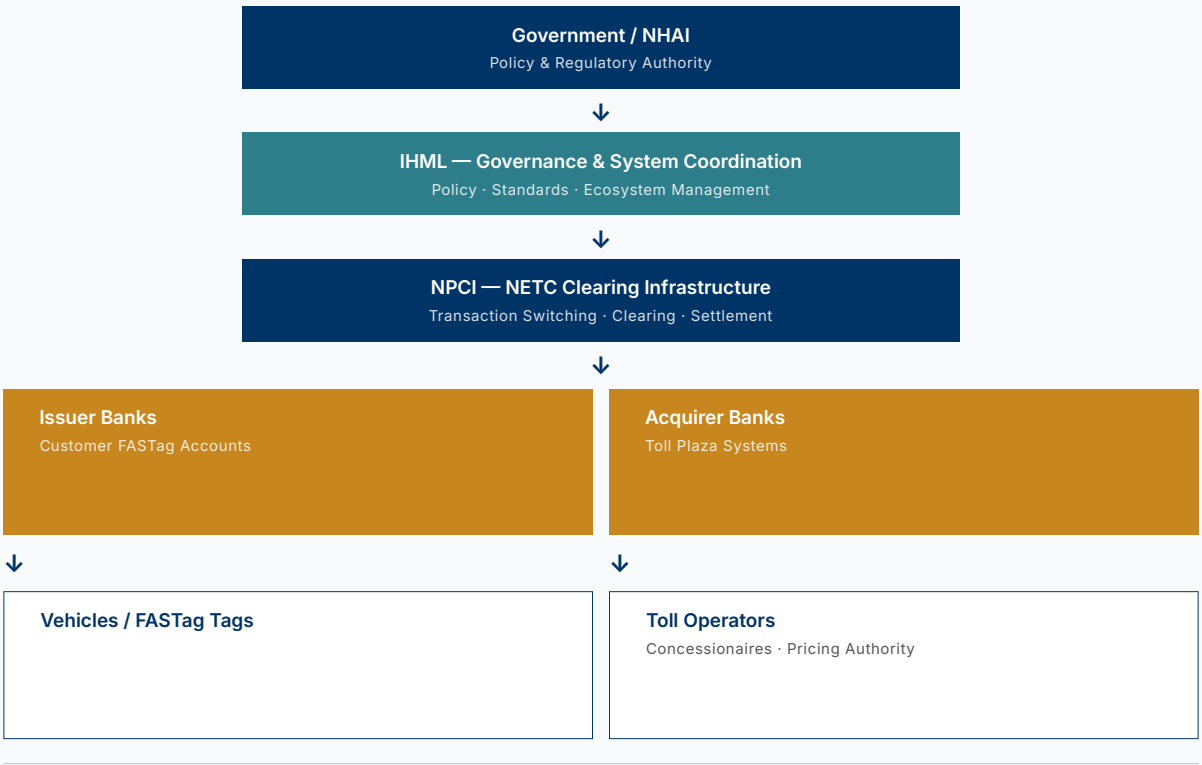
26	12	1,150+	10.6M	98%
CERTIFIED ISSUER BANKS	CERTIFIED ACQUIRER BANKS	TOLL PLAZAS	DAILY TRANSACTIONS	OF TOLL COLLECTIONS

FASTag enables electronic toll collection across highways operated by multiple concessionaires and authorities. Interoperability is achieved through standardized identification, transaction routing, and centralized clearing mechanisms, while toll operators retain control over pricing and validation:

- Operational execution remains distributed across toll operators

- Financial coordination is achieved through shared clearing and settlement
- National-scale interoperability is delivered without centralizing pricing control

FIG. 11 · FASTAG INSTITUTIONAL ARCHITECTURE — INDIA · CASE 01



FASTag separates infrastructure ownership, financial settlement, and governance across multiple institutions.

CASE 02 · EUROPE

EETS: Cross-Border Mobility and Sovereignty Constraints

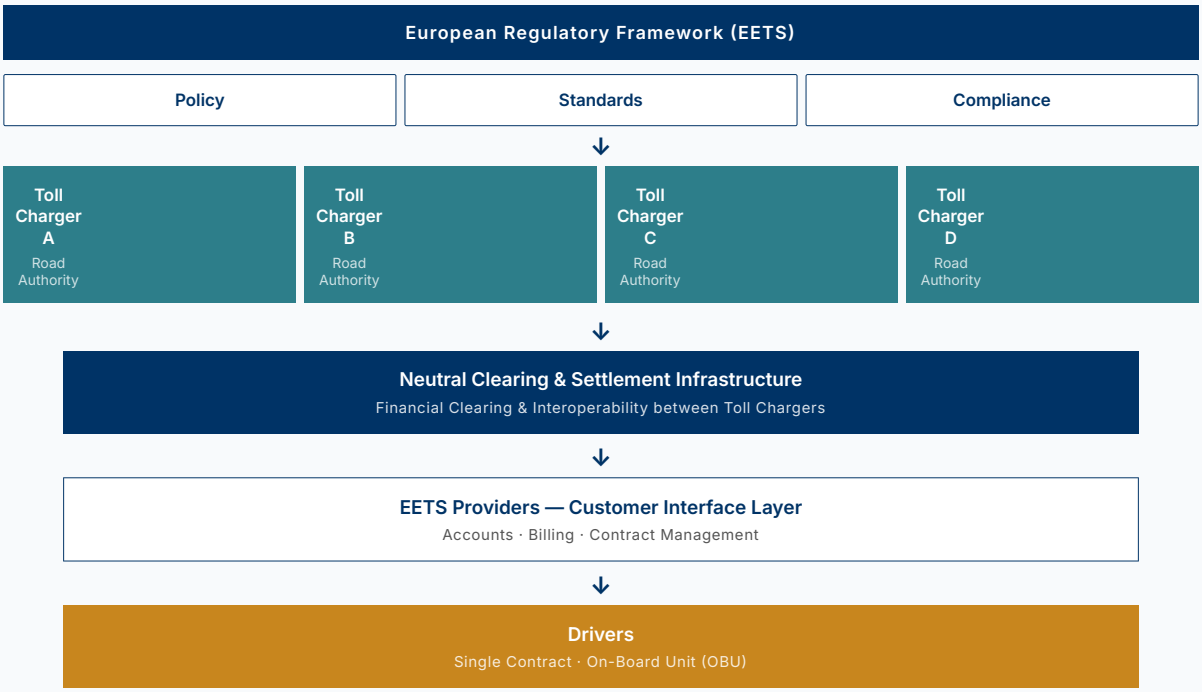
100+	140+	2
INDEPENDENT NATIONAL TOLLING SYSTEMS ACROSS THE EU	SEPARATE COMPANIES & GOVERNMENT AGENCIES	ACTIVE EETS PROVIDERS ENABLING CROSS-BORDER ACCESS

The European Electronic Toll Service enables cross-border tolling across multiple countries, each with its own regulatory and operational frameworks. Service providers act as intermediaries to facilitate coordination, while authorities retain control over tolling rules and revenue. The system demonstrates that:

- Interoperability must align with national sovereignty and regulatory diversity
- Coordination layers can span jurisdictions without altering authority control
- Scaling across borders requires preserving institutional independence

FIG. 12 · EETS INTEROPERABILITY ARCHITECTURE

EUROPE · CASE 02



EETS enables cross-border interoperability while preserving authority with infrastructure operators.

CASE 03 · UNITED STATES

Texas Mobility Model: Regional Coordination without Centralization

3

PRIMARY INDEPENDENT TOLL AUTHORITIES — TXDOT, NTTA, HCTRA

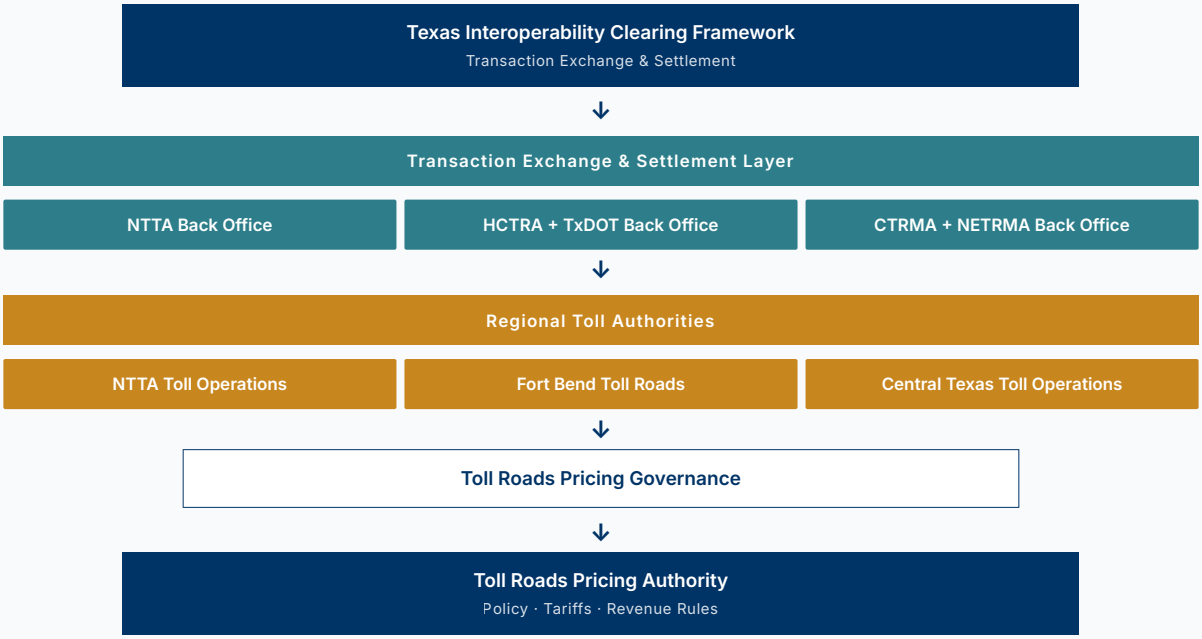
5

STATES — SINGLE TOLL TAG RECOGNIZED ACROSS TX, OK, KS, CO, FL

In Texas, mobility systems operate through regional coordination among multiple agencies and infrastructure operators. Integration is achieved through shared standards and cooperative frameworks rather than a single controlling platform — demonstrating that:

- Regional interoperability can be achieved through federated coordination
- Authorities retain operational autonomy within shared frameworks
- Financial and operational alignment can be structured without centralized control

FIG. 13 · TEXAS FEDERATED TOLLING ARCHITECTURE UNITED STATES · CASE 03



Texas toll interoperability operates through federated authorities rather than a centralized toll system.

11 — Governance in Practice: Principles from Real-World Systems

The case studies illustrate how interoperability can be achieved across independently governed mobility systems without consolidating authority. Despite differences in geography, regulation, and implementation, six principles emerge that define the structural requirements for scalable, multi-authority ecosystems.

- **Governance Separation Enables Ecosystem Scale.** FASTag scaled to national coverage across hundreds of toll operators; EETS extended interoperability across sovereign jurisdictions; Texas achieved regional coordination across independent authorities — all without centralizing institutional control. In each case, the ability to scale depended on keeping coordination, execution, and settlement in separate hands. Systems that attempted consolidation encountered resistance and fragmentation instead.
- **Authority Retains Control Over Policy and Pricing.** All three implementations demonstrate that interoperability does not require authorities to surrender pricing or policy control. These responsibilities remain with authorities rather than a central platform, and no implementation that attempted to absorb them into a coordinating entity succeeded at scale.
- **Settlement and Reconciliation Operate as Neutral Shared Infrastructure.** In all three implementations — NPCI NETC in FASTag, bilateral agreements in EETS, and interoperability arrangements in Texas — financial coordination was achieved through shared settlement mechanisms without any single entity owning or controlling the function. Settlement infrastructure that is neutral, consistent, and auditable is a precondition for ecosystem trust.
- **Governance Requires a Neutral Institutional Anchor.** Each implementation succeeded because a public sector body with statutory standing, no commercial stake in outcomes, and a cross-jurisdictional mandate acted as convenor. Identifying and empowering that institution — one whose authority derives from policy mandate rather than market participation — is the first act of governance-first implementation.
- **Policy Frameworks Accelerate Governance Alignment.** FASTag was mandated by India's Ministry of Road Transport; EETS operates under EU Directive 2019/520; Texas achieves interoperability through voluntary interstate agreements.

These represent three distinct policy pathways — regulatory mandate, legislative framework, and cooperative federalism — but in each case, policy alignment preceded and enabled architectural adoption.

- **Resistance is a Governance Signal, not an Architectural Failure.** EETS, despite being legally mandated since 2004, has achieved only 2 active service providers across more than 100 national tolling systems. This reflects institutional resistance when incumbent operators perceive coordination frameworks as threatening. Resistance should be read as a signal that institutional boundaries need clarification — not a reason to revert to centralized models. Governance design must precede system deployment.

These principles reinforce that scalable mobility systems depend on structured coordination across institutional participants — and that the path to governance-first architecture is as much a policy and institutional design challenge as it is a technical one.

12 — Future Mobility Infrastructure

The principles demonstrated by FASTag, EETS, and Texas are not endpoints — they are early indicators of a broader structural shift underway across global mobility infrastructure. Mobility systems are transitioning from isolated service networks to interconnected ecosystems that span jurisdictions, operators, and service types. As this transition accelerates, the primary constraint is no longer system capability, but the ability to coordinate across institutions while preserving governance boundaries. Future mobility infrastructure must therefore be designed as a shared coordination environment over distributed systems, rather than as a unified platform controlling all functions.

Three structural forces drive this shift:

- **First, the expansion of multi-modal journeys** — travel increasingly spans tolling, transit, parking, and emerging systems such as EV charging and road usage charging, all operating under different authorities and regulatory frameworks, requiring coordination without consolidation.
- **Second, the growth of cross-jurisdiction mobility** — systems are extending beyond regional boundaries into national and cross-border ecosystems, where interoperability must accommodate variations in legal structures, pricing regimes, and operational policies.
- **Third, the rising importance of financial transparency** — as systems interconnect, financial flows become more complex, and authorities require clear visibility into revenue attribution, settlement outcomes, and audit trails across multi-entity environments.

These forces reinforce a consistent requirement: future systems must enable interoperability without altering institutional roles. Mobility infrastructure will evolve along three corresponding dimensions:

- **From integration to federation**, as tightly integrated platform-centric models give way to federated structures where independent participants coordinate through shared frameworks
- **From platform control to governance alignment**, as the role of platforms shifts from controlling execution to enabling coordination with authority control preserved within infrastructure systems
- **From post-processing to real-time financial coordination**, as settlement systems operate closer to operational events, ensuring financial outcomes remain consistent and auditable as transactions occur

In this model, interoperability is sustained through standardized event models across systems, shared financial coordination mechanisms, and governance frameworks that define roles, access, and accountability — allowing new services and participants to be added without restructuring existing systems. The expansion of platforms does not define the future of mobility infrastructure. The ability to coordinate across independently governed systems with precision and trust does. Mobility ecosystems will scale not by centralizing control, but by structuring interoperability as a governed, federated system.

13 — Conclusion: The Mandate for a Federated Future

Mobility systems are converging at the experience layer, but remain structurally distributed at the institutional level. This is not a transitional condition — it is fundamental to how transport infrastructure is governed, financed, and operated. Designing around it, rather than against it, is the defining challenge for mobility architects, authorities, and regulators.

Centralized platforms fail at this challenge not because the technology is inadequate, but because they absorb decision rights that institutions must retain. The result is conflict in authority, revenue ownership, and accountability — conflicts that compound as systems scale across jurisdictions.

The Governance-First Architecture resolves this by separating orchestration, execution, and settlement into distinct, interoperable layers:

- Coordination is enabled without ownership
- Execution remains with the authorities
- Financial outcomes are consistent, traceable, and auditable without centralizing control

This is not a theoretical position — FASTag, EETS, and Texas demonstrate it at the national and cross-border scale.

The mandate is clear: mobility ecosystems will not scale through deeper integration alone. They will scale through architectures that recognize distributed governance as a structural reality — and are designed, from the settlement layer up, to coordinate within it.

— About the Author

Suresh Kakarla is the Founder of Toucan Payments LLC and co-founder of TollPlus LLC, with over two decades of experience across mobility infrastructure, transportation technology, and financial settlement systems spanning the United States, India, and Europe. Through TollPlus, he shaped global mobility markets and developed pan-country interoperability models across tolling, transit, and multi-modal ecosystems. Through Toucan Payments, he brings deep expertise in fintech platforms and payments settlement infrastructure. A graduate of Thunderbird School of Global Management in International Business, Suresh approaches mobility interoperability as fundamentally a governance and institutional design challenge — a perspective that underpins the framework presented in this paper.

— Appendix: Glossary

Governance-First Architecture	A system design approach that separates coordination, execution, and financial settlement to enable interoperability while preserving institutional control.
Federated Model	An operating structure in which independent participants coordinate through shared frameworks while retaining control over their respective systems and responsibilities.
Coordination Rights	The ability to manage journey flow, interaction sequencing, and system connectivity across services without influencing operational decisions.

Decision Rights	Authority to determine pricing, validate service usage, enforce policies, and control operational outcomes within a system.
Event-Linked Settlement	A financial coordination model where settlement outcomes are directly derived from operational events, ensuring alignment between system activity and financial records.
Revenue Segregation	Separation of financial flows based on their legal and operational context (e.g., tolling, statutory charges, commercial services) to maintain compliance and audit clarity.
Governance Control Plane	A cross-layer framework managing identity, access, consent, and participation rules without performing execution or financial functions.
Data Trusteeship	A governance model in which authorities retain ownership and control over data generated within their systems, with access granted through defined permissions and roles.