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Article

Cognitive Work Support in Hybrid Public Sector ERP Environments: A Failure Mode Taxonomy and Decision Interface Design for Automated Contract Release Value Governance

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Abstract: Hybrid public sector procurement environments — where a central procurement system, agency-specific enterprise procurement systems, and a financial enterprise resource planning platform operate in parallel — generate systematic contract release value synchronization failures that are structurally invisible at the point of occurrence. These failures expose state governments to over-commitment risk, obstruct valid agency procurement, and erode audit defensibility. This paper presents a novel seven-mode failure taxonomy organized across two governance failure dimensions and two agency-type boundaries, derived from multi-year forensic analysis of a live statewide multi-system procurement architecture. An automated contract reconciliation framework built on this taxonomy is described — implemented as a custom analytical transaction within the production statewide environment — achieving a reduction in reconciliation effort from three to four hours per contract tounder one minute per contract, exceeding 95 percent efficiency improvement. The framework instantiates a cross-system governance layer applying agency-type-appropriate diagnostic logic, reading close indicators from the authoritative system for each transaction channel, and structuring practitioner release value correction decisions through a human-authorized governance interface. The evidence suggests that financial control integrity in complex multi-system environments is not achievable through within-system controls alone — a finding with direct implications for cognitive work support design in high-stakes public sector financial governance contexts.

Keywords: public sector ERP governance; contract release value synchronization; failure mode taxonomy; design science; hybrid procurement architecture; cross-system governance

Background

The Governance Challenge in Hybrid Public Sector ERP Environments

Across U.S. state governments, the expectation underlying enterprise procurement modernization investments is that centralized systems will enforce governance controls, provide consolidated spend visibility, and ensure that financial commitments against contracts remain accurate and auditable throughout the procurement lifecycle (Thai, 2001; Coggburn, 2003). What this expectation does not account for is the architectural reality of statewide procurement as it actually operates: not as a single unified platform but as a hybrid of centralized and agency-specific systems — a central procurement system (CPS) managing contracts and release values, a financial enterprise resource planning (FERP) platform serving as the government-wide financial system of record, and agency-specific enterprise procurement systems (EPS) through which certain agencies create their own purchase orders rather than procuring through the CPS.

Contract release value records — the cumulative financial commitments posted against centrally managed contracts — are not maintained by a single system within this architecture. Whether a contract shows available capacity, whether an agency can authorize additional procurement, whether the release value position presented to a procurement officer reflects the actual financial position — each of these determinations depends on whether transactions in the FERP and EPS have propagated correctly to the CPS. When propagation fails, the divergence is

structurally invisible without a dedicated cross-system diagnostic capability. The practitioner operating the governance decision does not know the system-presented data is wrong. This is the problem the taxonomy and framework in this paper address.

The cognitive work stakes of this invisibility are not incidental. Release value correction decisions are consequential acts: authorizing additional spend against a contract showing phantom capacity creates over-commitment exposure; blocking procurement against a contract showing phantom consumption prevents agencies from using capacity that is legitimately available. No amount of training or procedural enforcement changes the information available to the practitioner when the error originates in cross-system integration architecture rather than individual user behavior.

Research Problem and Contribution

Despite well-documented recurring audit findings concerning public procurement financial controls (Government Accountability Office, 2014; Rendon & Rendon, 2016), the literature has not established a systematic, bidirectional, agency-type-scoped taxonomy of contract release value synchronization failures. ERP governance scholarship addresses integration failures generically (Themistocleous et al., 2004; Luna-Reyes et al., 2005) without differentiating by agency-type boundary or symptom direction. Cognitive engineering scholarship on governance interface design for multi-system financial environments remains similarly underdeveloped.

Three contributions address this gap. First, this paper establishes the first bidirectional, agency-type-scoped failure mode taxonomy for contract release value synchronization in hybrid public sector ERP environments — seven failure modes classified across two governance dimensions and two agency-type boundaries. Second, a design framework for an automated reconciliation tool is presented that operationalizes this taxonomy as a cognitive work support artifact, with a governance interface structured specifically to support the practitioner's correction authorization task. Third, the paper argues that recurring government contract audit findings are better understood as predictable architectural consequences of hybrid multi-system environments than as individual process failures — a reframing that shifts remediation logic from enforcement toward governance architecture design.

Background and Literature Review

Enterprise Systems Governance in Public Sector ERP Environments

The governance stakes of enterprise procurement systems in state government are substantial. While state governments collectively manage over $3.2 trillion in total annual expenditures (National Association of State Budget Officers, 2025), procurement systems provide the essential oversight and control mechanisms for the significant portion of those funds dedicated to the acquisition of goods, services, and infrastructure — a scale at which even small systematic divergences between recorded and actual contract positions carry material fiscal risk Against this backdrop, the persistence of procurement control weaknesses across jurisdictions indicates that system capability alone may be insufficient to ensure governance effectiveness (Norris & Reddick, 2013; Weerakkody et al., 2011).

Design science research provides the methodological grounding for this paper's artifact development approach. Hevner et al. (2004) establish that design science research produces knowledge through the construction and evaluation of artifacts that address specific, identified organizational or technical problems. Peffers et al. (2014) articulate a research methodology for IS design science that moves from problem identification through artifact conceptualization, design, demonstration, and evaluation — the sequence directly instantiated in this paper.

Multi-system integration failures in enterprise environments produce a class of governance problem that within-system controls cannot detect. Themistocleous et al. (2004) demonstrate that integration-layer failures — where systems interact through middleware or batch processes — generate governance gaps invisible from within any single participating system. Luna-Reyes et al. (2005) characterize multi-system IS development as emergent sociotechnical change, in which technical and organizational processes interact to produce outcomes neither analysis alone can fully predict.

Table 1. Summary of governance frameworks and applicability to hybrid ERP environments

Framework / Source	Core Governance Concept	Applicability to Hybrid ERP Context
Hevner et al. (2004)	Design science: artifact evaluation by utility	Grounds taxonomy + framework as IS research artifacts

Peffers et al. (2014)	DSR methodology: problem → artifact → evaluation	Structures the research pipeline in this paper
Luna-Reyes et al. (2005)	IS development as emergent sociotechnical change	Explains why integration failures are architecturally emergent
Themistocleous et al. (2004)	Integration-layer failures invisible within single systems	Directly anticipates the failure mode taxonomy
Government Accountability Office (2014)	Federal internal control standards (Green Book)	Benchmark for evaluating audit defensibility outcomes
Brous et al. (2020)	Cross-system coordination mechanisms for data governance	Supports the cross-system governance layer design argument

Cognitive Work Analysis in Complex Information Systems Environments

What the practitioner operating within a hybrid multi-system procurement environment needs from a governance interface is not more data — it is correctly classified, cross-system-integrated data structured to support a specific decision task. Vicente's (1999) cognitive work analysis (CWA) framework provides the theoretical foundation for designing such an interface: CWA analyzes the constraints of the work domain, the decision tasks the practitioner must perform, and the information requirements those tasks generate, then translates this analysis into interface design requirements.

Applied to the contract release value correction decision, CWA reveals a structured judgment task: the authorizing practitioner must determine whether a flagged discrepancy is directionally consistent with the transaction evidence, whether the calculated correction value is supported by document-level detail, and whether selective or bulk correction is appropriate. Meeting these requirements demands cross-system transaction visibility presented in a single decision view rather than distributed across multiple system transactions.

Brous et al. (2020) establish that decision-making coordination in multi-system data governance environments requires explicit cross-system coordination mechanisms — governance structures that operate above the level of any individual system and maintain consistency across system boundaries. The reconciliation framework instantiates precisely such a mechanism in the procurement financial control context.

Digital Transformation and Governance Architecture Innovation

Public sector digital transformation is increasingly understood as layering new governance capabilities onto existing multi-system architectures rather than replacing them (Weerakkody et al., 2011; Wirtz et al., 2018). Hwang's (2020) find that durable governance improvements in established public sector environments typically require architectural interventions — new coordination mechanisms, cross-system monitoring capabilities, or governance layers — that operate across and above existing system boundaries. The reconciliation framework is exactly this kind of architectural intervention.

Twizeyimana and Andersson (2019) identify transparency, accountability, and efficiency as the core value dimensions against which government digital systems should be evaluated. The reconciliation framework's contributions — greater than 95 percent efficiency improvement, item-level transaction lineage for auditors, and complete release value visibility across all agency channels — correspond directly to these three dimensions. Grisold et al. (2020) demonstrate that forensic process analysis enables theorizing about organizational change in complex system environments — the analytical approach used to derive the failure mode taxonomy here.

Method

Design Science Research Approach

The research problem addressed in this paper is an operational governance gap in an established production environment: contract release values recorded in the CPS systematically diverge from actual financial commitments, with no mechanism available to detect or correct these divergences automatically at portfolio scale. Design science research is the appropriate paradigm because the research question is constructive — how should a cross-system governance layer be designed to address this specific class of failure — rather than explanatory or predictive (Hevner et al., 2004; Peffers et al., 2014). The research artifact is the failure mode taxonomy and the automated reconciliation

framework. Evaluation takes the form of operational deployment in a live statewide environment serving more than 120 state agencies.

Forensic Analytical Approach and Data Sources

Failure mode identification proceeded through multi-year forensic analysis of the statewide multi-system procurement architecture. The analytical method followed four structured stages: systematic review of agency-reported release value discrepancy incidents; direct transaction-level investigation tracing each incident to its root transaction source across system boundaries; pattern recognition across incident types by agency type, transaction channel, and symptom direction; and iterative taxonomy development as structurally distinct incident types were identified and confirmed.

The analyst throughout this process was the author — the senior SAP functional architect for the statewide platform — with direct production access to transaction records across the CPS, FERP, and EPS environments. Grisold et al. (2020) characterize forensic process analysis as a rigorous method for grounding organizational theory in transaction-level operational evidence; each failure mode in the taxonomy reflects a confirmed, repeatedly observed transaction pattern. All institutional identifiers have been anonymized.

Scope and Generalizability

Derived from a single state government implementation, the taxonomy's generalizability is argued on structural grounds. The failure modes reflect architectural characteristics shared by any state government operating a centralized procurement platform alongside agency-specific legacy systems. The taxonomy's organizational principles — governance failure dimension, agency-type boundary, symptom direction — are structurally portable to comparable architectures.

Failure Mode Taxonomy

The Hybrid Multi-System Procurement Architecture

Three systems define the procurement architecture analyzed in this paper. The central procurement system (CPS) manages contract creation, sourcing workflows, and release value recording. The financial enterprise resource planning platform (FERP) processes all financial transactions regardless of which procurement channel generated them, functioning as the government-wide financial system of record. Agency-specific enterprise procurement systems (EPS) are legacy procurement platforms through which certain agencies create purchase orders recorded in the FERP directly, interacting with the CPS only through integration middleware.

Two agency-type boundaries organize the architecture and the taxonomy. CPS agencies procure exclusively through the central platform. EPS agencies retain their own procurement environments; purchase orders are created in the EPS, posted directly to the FERP, and reflected in the CPS release value only through integration processing. Whether a given failure mode is architecturally possible for a given agency depends entirely on which channel that agency uses.

Figure 1: Multi-System Procurement Architecture, Agency Types, Close Indicator Locations, and Failure Mode Locations

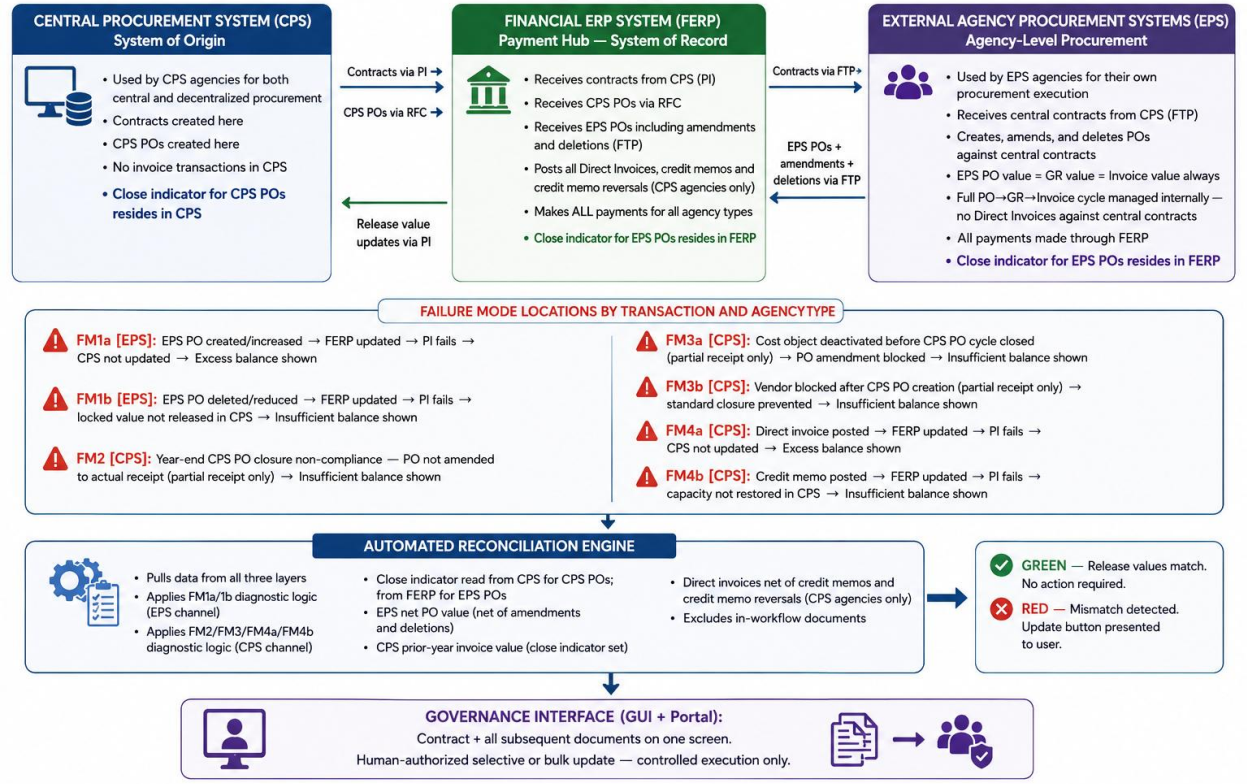

Figure 1. Hybrid multi-system procurement architecture: CPS, EPS, FERP channels and integration points.

Two Governance Failure Dimensions

Integration-layer failures arise from breakdowns in the process integration connections between systems: transactions occurring in the FERP or EPS that should update the CPS release value record fail to do so, or fail to do so correctly. Both agency types are exposed to integration-layer failures, but through structurally distinct transaction channels — EPS agencies through purchase order lifecycle events, CPS agencies through direct invoice and credit memo processing.

Enterprise lifecycle governance failures arise within the CPS agency channel from purchase order lifecycle management constraints that prevent standard system closure of partially utilized purchase orders. These constraints — cost object inactivity, vendor master blocking, fiscal year boundary logic — leave committed values locked against the contract release balance beyond the point at which they represent genuine current obligations. Lifecycle governance failures are structurally impossible in the EPS channel because EPS purchase order values are internally consistent across their lifecycle.

Seven Failure Modes

Seven failure modes constitute the taxonomy, organized by governance failure dimension, agency-type boundary, and symptom direction.

FM1a — EPS Purchase Order Upward Amendment or New Purchase Order Not Propagated (Integration-layer; EPS agencies; Excess balance shown): A new EPS purchase order or an upward amendment is created in the FERP but not reflected in the CPS release value record. The CPS understates actual consumption, presenting apparent contract capacity that does not exist, creating over-commitment risk.

FM1b — EPS Purchase Order Deletion or Downward Amendment Not Propagated (Integration-layer; EPS agencies; Insufficient balance shown): An EPS purchase order deletion or downward amendment reduces the actual financial commitment in the FERP, but the CPS release value record retains the original committed value. Capacity legitimately released by the deletion is not restored, blocking valid procurement.

FM2 — Partially Utilized CPS Purchase Order, Prior Year Close, Residual Balance Locked (Lifecycle governance; CPS agencies; Insufficient balance shown): A CPS purchase order that was only partially utilized receives a fiscal year-end close indicator, but the residual balance is not released to available contract capacity, locking legitimate capacity for subsequent procurement periods.

FM3a — Cost Object Constraint Preventing CPS Purchase Order Closure (Lifecycle governance; CPS agencies; Insufficient balance shown): A CPS purchase order cannot be processed through standard closure because the cost object has been closed or marked inactive in the FERP subsequent to the purchase order's creation. SAP SE (2015) documents the underlying technical constraint in the PPS-scenario distribution context.

FM3b — Vendor Lifecycle Constraint Preventing CPS Purchase Order Closure (Lifecycle governance; CPS agencies; Insufficient balance shown): A CPS purchase order cannot be processed through standard closure because the vendor master record has been blocked or marked for deletion in the FERP after the purchase order was created. SAP SE (2020) documents the relevant PPS-scenario constraint.

FM4a — Direct Invoice Not Propagated to CPS (Integration-layer; CPS agencies; Excess balance shown): A direct invoice posted in the FERP outside the standard CPS procurement workflow is not reflected in the CPS release value record, creating excess available balance.

FM4b — Credit Memo or Reversal Not Propagated to CPS (Integration-layer; CPS agencies; Insufficient balance shown): A credit memo or credit memo reversal is not propagated correctly from the FERP to the CPS, causing the CPS to over-state consumption and block procurement against legitimately released capacity.

Table 2. Failure mode classification matrix

Failure Mode	Dimension	Agency Type	Symptom Direction	Root Cause
FM1a	Integration-layer	EPS agencies	Excess balance shown	EPS PO upward amendment / new PO not propagated to CPS
FM1b	Integration-layer	EPS agencies	Insufficient balance shown	EPS PO deletion / downward amendment not propagated to CPS
FM2	Lifecycle governance	CPS agencies	Insufficient balance shown	Partially utilized PO close indicator set; residual not released
FM3a	Lifecycle governance	CPS agencies	Insufficient balance shown	Cost object inactivity prevents standard PO closure
FM3b	Lifecycle governance	CPS agencies	Insufficient balance shown	Vendor master blocking prevents standard PO closure
FM4a	Integration-layer	CPS agencies	Excess balance shown	Direct invoice not propagated to CPS release value
FM4b	Integration-layer	CPS agencies	Insufficient balance shown	Credit memo / reversal not propagated to CPS release value

Bidirectional Symptom Patterns and Their Governance Consequences

The bidirectionality of the failure population carries a governance consequence not immediately obvious from reviewing individual failure modes in isolation. Excess balance conditions — FM1a, FM4a — create over-commitment risk; insufficient balance conditions — FM1b, FM2, FM3a, FM3b, FM4b — block valid procurement. A reconciliation tool designed to detect only excess balance conditions would leave all five insufficient balance failure modes unaddressed. Effective cross-system governance therefore requires bidirectional diagnostic capability implemented simultaneously across both agency-type channels.

Automated Contract Reconciliation Framework

Framework Design Principles

Four principles governed the reconciliation framework's design. Agency-type-aware diagnostic logic reflects the finding that agency-type boundary determines failure mode exposure. Close-indicator-based budget year logic with

system-appropriate indicator source reflects that close indicators reside in different systems for different transaction channels — in the CPS for CPS purchase orders, in the FERP for EPS purchase orders. Bidirectional correction capability reflects the governance finding that both symptom directions require detection and correction within the same workflow. Human-authorized governance interface reflects the cognitive work support principle that the framework structures the practitioner's correction decision but preserves human judgment as the authorizing act.

Release Value Calculation Logic

Four calculation rules implement the framework's aggregation logic. Current-year CPS purchase orders are counted at their full original commitment value. Prior-year CPS purchase orders are counted at the actual invoice amount from the FERP, identifying FM2 and FM3 conditions. EPS purchase orders are counted at net lifecycle value with close indicators read from the FERP, directly addressing FM1a and FM1b. Direct invoices in the CPS agency channel are counted net of credit memos and reversals, addressing FM4a and FM4b. In-workflow documents pending approval are excluded before calculation across all channels.

Table 3. Release value reconciliation formula by transaction channel

Channel	Close Indicator Source	Calculation Method	Failure Modes Addressed
CPS POs — Current Year	CPS (not set)	Full original PO value	Baseline — no discrepancy
CPS POs — Prior Year	CPS (set)	Actual invoice amount from FERP	FM2, FM3a, FM3b
EPS POs	FERP	Net lifecycle value (post-amendments; deletions excluded)	FM1a, FM1b
Direct Invoices (CPS agencies)	N/A	Net of credit memos and reversals	FM4a, FM4b
In-workflow documents	N/A	Excluded from all channels	All modes — prevents distortion

Governance Interface Design

The governance interface organizes the release value correction decision into a dual-panel display that consolidates all information required for the authorization judgment on a single screen — a design principle derived directly from the CWA requirement that the interface structure the decision task rather than merely presenting raw data (Vicente, 1999).

The upper panel presents contract-level and item-level release value details with green/red status indicators per line item. Red-flagged items present Update Selected and Update All controls. The lower panel displays the transaction detail underlying the calculated position — document type, document number, agency-type channel, contract item reference, item value, and quantity — enabling the authorizing practitioner to trace the complete transaction basis before authorizing any correction.

The cognitive work support contribution is structural. Presenting classified, cross-system-integrated transaction evidence within a single decision view transforms the practitioner's task from multi-system forensic investigation — which previously consumed three to four hours per contract — to structured authorization review.

Access Control and Implementation

The framework is executed exclusively by the central financial authority. Individual agencies do not have direct access to the reconciliation tool. The current implementation operates in two execution modes: proactive portfolio monitoring and reactive incident response. The absence of a transaction-level audit log in the current implementation is the primary recognized limitation — full audit logging is the prerequisite for broader agency-level deployment and for satisfying internal control standards (Government Accountability Office, 2014).

The author developed the complete functional specification for the framework; technical coding was performed by a software developer working to those specifications. The framework was deployed within the live statewide

production environment through a phased implementation with a parallel-running validation period confirming all discrepancy categories identified correctly across both agency-type channels.

Results and Discussion

Operational Outcomes

Contract reconciliation time declined from three to four hours — the baseline established through direct observation of the manual process — to under one minute per contract...enabling rapid on-demand reconciliation of any contract in the active portfolio. The greater than 95 percent improvement transforms the governance capability: reconciliation moves from a periodic, resource-intensive manual task applied to individual contracts on demand to a continuous automated monitoring function applied to the entire portfolio simultaneously.

Five additional governance outcomes were documented. Item-level transaction lineage by document type and agency-type channel substantially improved audit defensibility. Procurement officers gained complete release value visibility across all participating agencies regardless of agency type. Integration-layer failure detection was established in both symptom directions across both agency-type channels. Bidirectional discrepancy resolution became operational within the same governance workflow. Agency-type-differentiated diagnostic logic is applied consistently across the full portfolio for every contract in every execution.

Table 4. Pre/post framework governance outcome comparison

Outcome Area	Baseline (Pre-Framework)	Post-Implementation
Reconciliation time	3–4 hours per contract (manual, per-contract)	Under 1 minute per contract
Efficiency improvement	Baseline	Greater than 95 percent
Audit defensibility	No systematic documentary evidence	Item-level transaction lineage per document type and agency-type channel
Statewide contract visibility	Partial — CPS-channel only	Complete — all agency types, both channels
Failure detection coverage	Ad hoc, incident-driven, unidirectional	Systematic, bidirectional, both agency-type channels
Discrepancy resolution	Manual, per-contract, separate processes per direction	Automated portfolio-level, bidirectional, single workflow
Diagnostic logic	None — manual judgment	Agency-type-differentiated, channel-appropriate close indicator logic

Theoretical Contributions

Three contributions extend the enterprise systems governance and cognitive engineering literatures. The bidirectional, agency-type-scoped failure mode taxonomy represents a new governance layer concept for multi-system public sector ERP environments: the taxonomy demonstrates that agency-type boundary determines failure mode exposure and that bidirectionality requires bidirectional correction logic. The demonstration that cross-system governance must read close indicator values from the authoritative source system for each transaction channel extends the enterprise IS governance literature with a specific and actionable design principle. Reframing recurring audit findings as predictable architectural outcomes of hybrid multi-system procurement environments shifts the prescriptive implication from enforcement and training toward governance architecture design (Government Accountability Office, 2014; Rendon & Rendon, 2016), consistent with Hwang's (2020) institutional change analysis.

Implications for Cognitive Work Support Design

The governance interface illustrates a cognitive work support principle applicable beyond the procurement context: in high-stakes decision environments where the practitioner's judgment task depends on data distributed across multiple systems that do not maintain mutual consistency, the cognitive support artifact must perform the cross-

system integration and failure mode classification before presenting the decision to the practitioner — not merely aggregate and display raw data from each system separately (Vicente, 1999; Brous et al., 2020).

What reduces cognitive load is pre-classification: the failure mode taxonomy, the channel-specific calculation logic, and the bidirectional discrepancy detection are all applied before the practitioner sees the result. The practitioner's task becomes authorization, not investigation. Dwivedi et al. (2021) identify the design of advanced decision support capabilities for public sector governance as a research and practice priority; the reconciliation framework demonstrates, in a concrete deployed context, how embedded diagnostic logic can transform the nature of the practitioner's cognitive task.

Limitations

Three limitations bound the findings. The taxonomy and framework were developed and validated within a single state government implementation; cross-jurisdictional empirical validation has not been conducted. The current implementation's absence of a transaction-level audit log restricts deployment to the central financial authority and represents a gap relative to full internal control compliance standards (Government Accountability Office, 2014). The framework addresses discrepancy identification and correction, not root cause remediation: each failure mode requires separate underlying remediation that is beyond the scope of the reconciliation framework itself.

Conclusion

Contract release value synchronization failures in hybrid public sector ERP environments are not anomalies — they are structural consequences of the architectural choices that most U.S. state governments have made: centralized procurement platforms operating alongside persistent agency-specific legacy systems, connected through process integration middleware that cannot guarantee bidirectional transaction propagation. The failure mode taxonomy established in this paper makes visible a class of governance problem previously experienced as a series of individual, unexplained discrepancies — and provides the analytical foundation for a systematic governance response.

What the automated reconciliation framework demonstrates is that such a response, when grounded in a rigorous failure taxonomy and designed around the cognitive work requirements of the authorizing practitioner, can accomplish more than efficiency recovery. Reducing reconciliation effort by more than 95 percent while simultaneously improving audit defensibility, expanding spend visibility, and enabling bidirectional discrepancy detection across both agency-type channels represents the replacement of a manual, episodic, and cognitively demanding governance task with a continuous, automated, and decision-structured governance capability. Only an explicit cross-system governance layer can provide the foundation for reliable financial control in multi-system environments where no individual system maintains accurate cross-system financial position data.

Future research should pursue several directions. Empirical cross-jurisdictional survey research would establish whether the taxonomy's seven modes represent a comprehensive and generalizable classification. Machine learning approaches to predictive discrepancy detection represent a technically promising extension. Audit logging architecture development is the most operationally urgent research direction. Longitudinal evaluation of governance outcomes across multiple budget cycles would provide evidence on whether post-implementation improvements are stable over time.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author Note

The author is an Enterprise ERP Functional Architect with over 24 years of progressive experience designing, implementing, and governing enterprise information systems across regulated industries including U.S. state government, energy, pharmaceutical manufacturing, and industrial manufacturing. The reconciliation framework described in this paper was conceived and designed by the author, who developed the failure mode taxonomy, agency-type scope boundaries, diagnostic logic, release value calculation methodology, governance design principles, and complete functional specifications. Technical coding was performed by a software developer working to the author's specifications. This paper is based on an implementation conducted within a state government central financial authority. All institutional identifiers have been anonymized.

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