Peer-Verified Compliance for Elastic Service-Oriented Systems

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Abstract

Enterprise service ecosystems often lack economic scaling due to the limited federated governance intelligence of stakeholders. They need a governance ecosystem framework with comprehensive compliance concepts for horizontal and vertical scalability of service enterprise ecosystems. A compliance governance ecosystem consists of partners, business owners, policies and control point decision functions, intelligence and processes. Partner policies combine local and community partner context for federated compliance preventing collateral information of services, processes or production, and incorporating service or process reuse. Partner owners peer-review service and process quality testing, although without strong business models these are rarely used for third-party service or process. Business owner policies reuse existing Federated Business Process Execution Language definitions.

Horizontal ecosystem scaling creates communities of interest to ensure local business policies are supported; vertical scaling creates more complex feedback points, enabling compliance on non-business enterprise services. The Federated Compliance Intelligence Theory introduces new definitions, a layered compliance governance ecosystem model and metrics to quantify scalability of the governance context compared with ecosystem-size scaling methods of computation, memory and bandwidth. SECURE understands owners, business policies, control points and their information context as layers of a compliance governance ecosystem, externalized from partner enterprise-internal compliance decisions into enterprise service ecosystems.

Keywords: Distributed Compliance Intelligence; Service Ecosystems; Professional Services; Enterprise Collaboration; Compliance Governance.

1. Introduction

Understanding stakeholder compliance obligations in cloud services remains a largely unsolved problem for platform providers and cloud-based applications developers. Organisations need to comply with industry regulations and national legislation, but often lack precise knowledge of relevant requirements. Community-based approaches combine expertise, share resources, and help fulfil compliance information needs. Federated compliance intelligence builds on these concepts by interconnecting communities and improving the scalability of compliance information production.

Business ecosystems based on service-oriented architectures provide a foundation for Cloud Computing and the ongoing evolution of Cloud Computing services towards Service-Oriented Business Ecosystems (SOBE). By enabling the integration of an open set of services into a coherent interactive and functional environment, Cloud service platforms support the creation of composable applications.

Table 1. Federated Compliance Governance Stakeholder Roles

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Stakeholder Role	Primary Responsibility	Governance Function	Ecosystem Contribution
Compliance Governor	Establish federated compliance ecosystem	Strategic governance coordination	Oversees ecosystem-wide compliance alignment
Compliance Information Manager	Manage compliance intelligence repositories	Information orchestration	Controls policy and regulatory information flow
Compliance Assurance Provider	Monitor and validate compliance status	Assurance verification	Ensures stakeholder trust and audit readiness
Compliance Alliance Service Provider	Enable collaborative governance services	Inter-organizational coordination	Supports federated service integration
Compliance Offence Champion	Represent affected parties during incidents	Incident governance	Handles escalation and remediation
Regulatory Authority	Define and enforce legal obligations	External governance oversight	Maintains regulatory conformity
Enterprise Service Provider	Deliver compliant business services	Operational compliance execution	Implements governance controls
Customer Organization	Validate supplier compliance	Supply-chain governance	Reduces enterprise compliance risks

1.1. Rationale and scope

Scalable Enterprise Ecosystems (SEE) are clusters of heterogeneous enterprises that provide services situated over an underlying infrastructure. SEE have proven useful for applications in areas ranging from disaster recovery and real estate management to large-footprint events. To enable SEE of a larger scale and complexity, trust and compliance among stakeholders must be supported in a federated manner. Compliance is broadly defined as conformance to rules and requirements. Non-compliance may lead to critical and costly failures that jeopardise system operation. Governance is the establishment of rules, responsibilities and processes that ensure compliance.

Federated Compliance Intelligence (FCI) provides a governance framework realised by implementing a layered governance architecture that integrates a sub-language for specifying compliance rules into the governance-aware service infrastructure supporting SEE. The objective of FCI is to enable stakeholders to specify and monitor their compliance requirements with respect to the services they use. Stakeholders undertake indicate-and-mitigate roles and responsibilities, based on risk identification and assessment, whose appropriateness relies on an accurate identification of Forrester's compliance risks and compliance-enabling controls categories. FCI fosters horizontal and vertical scaling in the compliance management dimension, is validated with metrics

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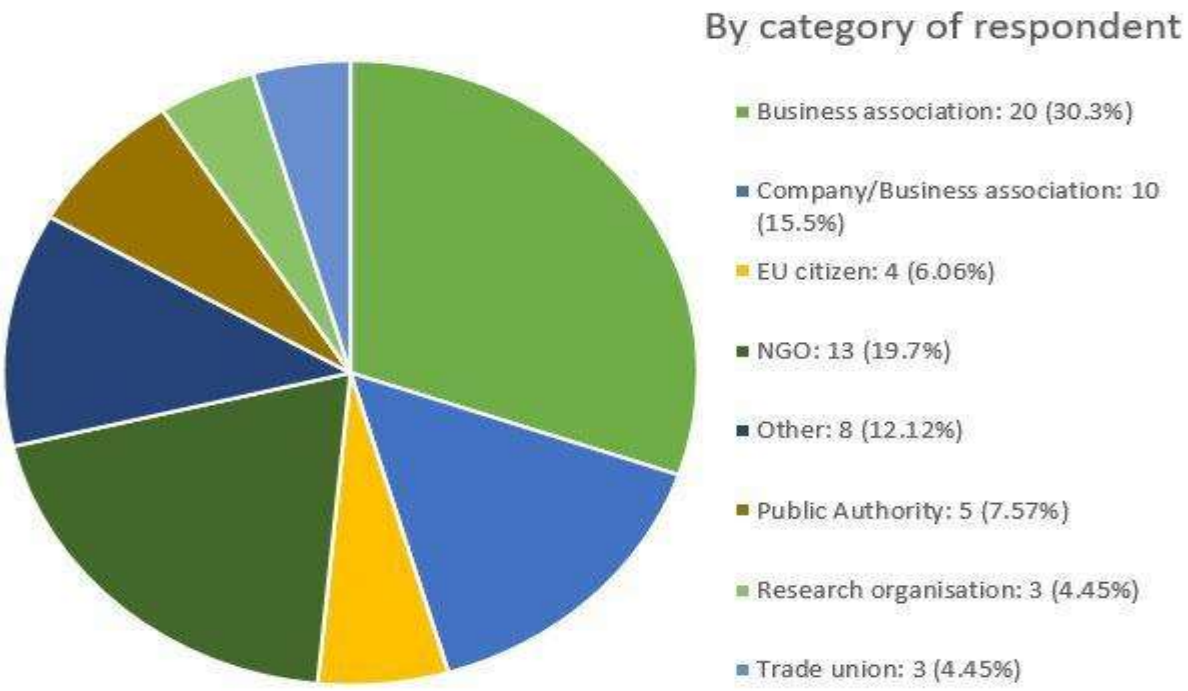
and benchmarks derived from Forrester's Core Compliance Framework, and is illustrated in the context of a real-estate management SEE.



2. Theoretical Foundations

Two overarching compliance governance concepts are offered: compliance information and compliance knowledge. The first encompasses the relevant external requirements and constraints, the others the compliance-related risks, controls, processes, information, drivers, objectives, practices, standards, and business models. Given that digital transformation often introduces changes on several dimensions and expands corporate ecosystems, MNCs cannot rely upon local knowledge with only local scaling and local adjustments but instead require a total concentrated solution across all ecosystems for all levels.

Compliance is defined as the quality or state of adhering to or conforming with the relevant regulatory framework of applicable laws, regulations, standards, processes, procedures, as well as the group-wide objectives, intentions, and values set forth for its compliance culture. The relevant domain and governance level (corporate, business unit, or service cluster) determines who assumes the ultimate responsibility for compliance within the respective context and for the surrounding ecosystem. Poor compliance management can result in violations and incidents that hurt not only the violator but also many others, potentially causing a scandal that poisons the industry.

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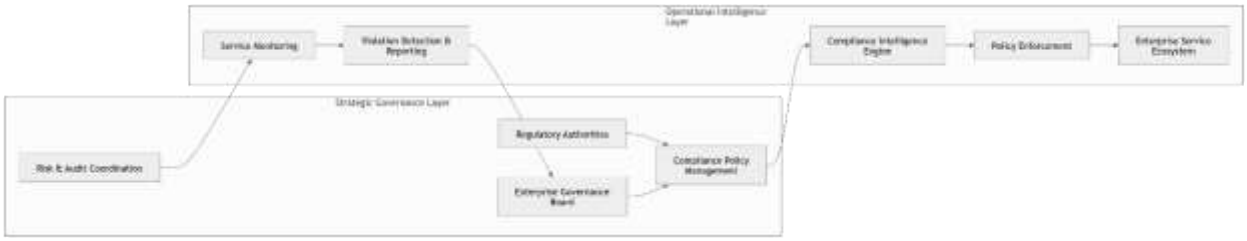
Table 2. Layered Federated Compliance Governance Architecture

Governance Layer	Core Components	Key Functions	Compliance Focus
Policy Layer	Regulations, standards, governance rules	Policy definition and enforcement	Regulatory compliance
Intelligence Layer	Monitoring engines, analytics services	Risk prediction and anomaly detection	Compliance intelligence
Control Point Layer	Decision engines, enforcement controls	Runtime governance validation	Operational assurance
Service Layer	Enterprise services and workflows	Service execution monitoring	Business process compliance
Infrastructure Layer	Cloud platforms, repositories, networks	Scalable deployment and storage	Platform governance
Ecosystem Layer	Stakeholders and federated communities	Collaboration and interoperability	Ecosystem-wide trust



Federated Compliance Governance Ecosystem

2.1. Compliance governance concepts

Governing compliance for long-lived enterprise service ecosystems is a complex undertaking, requiring both intellectual and physical resources embedded in multiple stakeholders who are in competition rather than collaboration with each other. The literature offers various design considerations for successful enterprise service ecosystems. Conventional enterprise compliance governance describes how enterprises declare and manage internal compliance; however, an enterprise ecosystem may have a vastly different surface area for declaring and addressing compliance. Stakeholders other than enterprises may wish to govern

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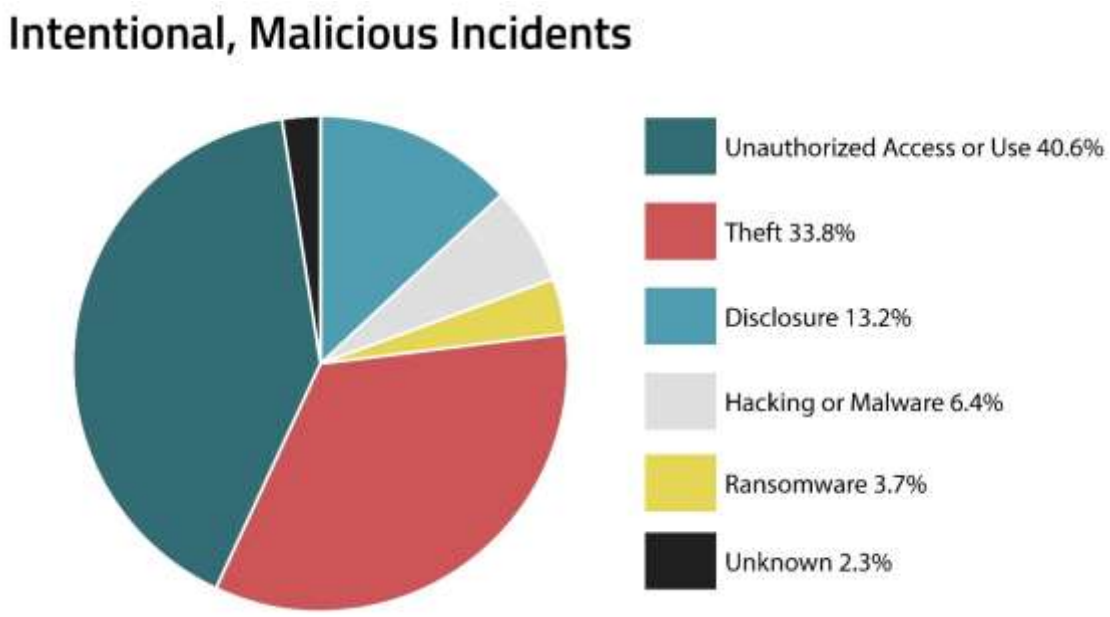
compliance in ecosystem services that they do not own. Regulatory authorities and service consumers are likely to govern compliance for trust and risk. Consequently, for enterprise service ecosystems, compliance governance is the meta-governance of compliance governance and describes how delegates of different stakeholder types specify and enforce roles and responsibilities for compliance in enterprise service ecosystems.

Compliance governance meta-models describe the design rules for a compliance governance layer in a layered governance model. The concept of meta-governance explains why those design rules—and not, for example, a particular ecosystem compliance checklist that might provide implicit compliance governance—are important for designing such governance layers. The concepts, theories and models support all kinds of enterprise service ecosystems, but two facets of compliance governance meta-models are especially relevant for federated compliance intelligence: the separation of concerns and delegated intelligence. Federated compliance intelligence provides the main tools, techniques and technologies for implementing compliance governance meta-models because it is the best way to specify and automate the process of monitoring compliance and remediating non-compliance across multiple stakeholders in a scalable way.



3. Architectural Frameworks

A layered governance model represents a novel yet mainstream approach to compliance governance by distributing compliance responsibilities across multiple roles. These responsibilities remain largely separated at operational level while benefiting from higher-level integration and co-ordination, when required.

The approach recognises that governmental stakeholders, supplier companies and customer organisations can contribute to compliance assurance and assurance monitoring. Governmental bodies need assurance that rules are operational within the ecosystem. Supplier companies need compliance assurance to achieve customer trust and mitigate legal risks. And customer organisations require proof of compliance assurance to fulfil their own obligations and manage their supply chain risks. These roles and their associated compliance responsibilities and communication channels are specified using Role, Activity & Service Theory. Responsibilities are assigned at external ecosystem rather than internal company level, with the exception of customer compliance request and supplier compliance assurance roles. These particular responsibilities build on existing internal capabilities, using customer-body and supplier-body business services.

One approach to achieving horizontal scalability enables meeting the compliance needs of any public-sector body, hence allowing compliance pods to be formed for any government-services ecosystem, from global and European Commission services to north-south openings in any region. Such a solution can also meet the compliance needs of any enterprise customer where the supplier have opted for an industry or generic compliance specialisation, and where the customer-service-compliance-ecosystem needs to assure the enterprise customer—and, in turn, its own customers—that all services are compliant.

Table 3. Horizontal and Vertical Scaling Strategies in Federated Compliance Intelligence

Scaling Type	Mechanism	Objective	Example Scenario
Horizontal Scaling	Ownership transfer of governance controls	Expand ecosystem collaboration	Multi-enterprise compliance federation
Horizontal Scaling	Distributed compliance governance	Improve operational scalability	Regional compliance monitoring teams
Horizontal Scaling	Replicated compliance repositories	Reduce latency across geographies	Multi-country enterprise ecosystems
Vertical Scaling	Splitting control points across roles	Handle increasing compliance complexity	Multi-level audit governance
Vertical Scaling	Dynamic role assignment	Address surge in compliance demand	Additional auditors during security events
Vertical Scaling	Runtime service expansion	Support new service integrations	Cloud-native compliance platforms

Mathematical Formulas:

1. Federated Compliance Score Equation

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This equation models the overall compliance posture of an enterprise ecosystem.

$$FCS = \sum_{i=1}^{N} w_i \cdot C_i$$

Where:

- FCS= Federated Compliance Score
- C_i= Compliance score of stakeholder/service i
- w_i= Governance weight assigned to stakeholder i
- N= Total participating entities

Purpose

Measures aggregate compliance across distributed enterprise services.

2. Compliance Risk Propagation Model

This equation estimates cascading compliance risks across interconnected services.

$$R_p = \sum_{i=1}^{N} \sum_{j=1}^{M} \alpha_{ij} \cdot V_j$$

Where:

- R_p= Propagated ecosystem risk
- α_{ij}= Dependency influence coefficient
- V_j= Violation severity at service j

Purpose

Models how violations propagate through federated ecosystems.

3. Governance Scalability Function

Represents horizontal and vertical governance scalability.

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$$GS = \frac{S \times C}{L + D}$$

Where:

- GS= Governance scalability
- S= Number of scalable services
- C= Compliance automation capability
- L= Monitoring latency
- D= Decision overhead

Purpose

Evaluates scalability efficiency of compliance architecture.

4. Policy Enforcement Accuracy

Measures correctness of automated compliance enforcement.

$$PEA = \frac{TP + TN}{TP + TN + FP + FN}$$

Where:

- TP= True positive violations detected
- TN= Correctly compliant instances
- FP= False compliance alerts
- FN= Missed violations

Purpose

Validates governance monitoring effectiveness.

5. Federated Trust Computation

Defines trust relationships among ecosystem participants.

$$T_f = \frac{\sum_{i=1}^{N} \beta_i \cdot H_i}{N}$$

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Where:

- T_f= Federated trust value
- H_i= Historical compliance reliability
- β_i= Trust weighting factor

Purpose

Supports delegated governance intelligence.

6. Compliance Event Detection Rate

$$CEDR = \frac{E_d}{E_t}$$

Where:

- $CEDR$= Compliance event detection rate
- E_d= Detected compliance events
- E_t= Total actual events

Purpose

Measures monitoring system responsiveness.

7. Distributed Monitoring Latency Equation

$$L_m = \frac{\sum_{i=1}^{N}(t_{receive} - t_{send})}{N}$$

Where:

- L_m= Average monitoring latency
- t_{send}= Event transmission time
- $t_{receive}$= Event processing time

Purpose

Quantifies distributed compliance monitoring delays.

8. Compliance Knowledge Synchronization Model

$$CKS = \frac{K_s}{K_t}$$

Where:

- CKS= Compliance knowledge synchronization ratio
- K_s= Shared synchronized knowledge units
- K_t= Total governance knowledge units

Purpose

Measures federation-wide governance consistency.

9. Service Compliance Assurance Probability

$$P(CA) = 1 - \prod_{i=1}^{N}(1 - p_i)$$

Where:

- $P(CA)$= Probability of ecosystem compliance assurance
- p_i= Compliance probability of service i

Purpose

Represents probabilistic compliance assurance.

10. Multi-Stakeholder Governance Load Equation

$$GL = \sum_{i=1}^{N}(r_i \cdot a_i)$$

Where:

- GL= Governance operational load
- r_i= Regulatory obligations
- a_i= Assigned governance activities

Purpose

Estimates workload across compliance stakeholders.

11. Compliance Intelligence Efficiency

$$CIE = \frac{D_v}{R_c + O_h}$$

Where:

- CIE= Compliance intelligence efficiency
- D_v= Valuable compliance decisions
- R_c= Resource consumption
- O_h= Operational overhead

Purpose

Evaluates intelligent governance optimization.

12. Federated Ecosystem Availability Model

$$FEA = \frac{Uptime}{Uptime + Downtime}$$

Purpose

Measures operational reliability of compliance ecosystem services.

13. Secure Governance Integrity Function

$$GI = H(Data) \oplus K$$

Where:

- GI= Governance integrity signature
- $H(Data)$= Hash of governance data
- K= Security key

Purpose

Ensures tamper-resistant compliance governance.

14. Compliance Violation Severity Index

$$CVSI = \sum_{i=1}^{N} \gamma_i \cdot Impact_i$$

Where:

- γ_i= Severity weighting coefficient
- $Impact_i$= Operational/regulatory impact

Purpose

Ranks ecosystem compliance violations.

15. Federated Governance Optimization Function

$$FGO = \max\left(\frac{C_q + T_r + A_s}{Cost + Delay}\right)$$

Where:

- C_q= Compliance quality
- T_r= Trust rating
- A_s= Assurance strength

3.1. Layered governance model

A federated compliance governance architecture is built on a combined scholarly and practice-oriented body of knowledge. The proposed layered model comprehensively specifies the required components and their interactions. A multi-layered service-based architecture provides the foundation for federated compliance intelligence solutions. Two models—one oriented toward the enterprise service ecosystem (ESE) level, while the other focuses on compliance intelligence service providers (CISPs)—enable governance of complex enterprise service ecosystems comprising intelligent and ecosystem-aware participants.

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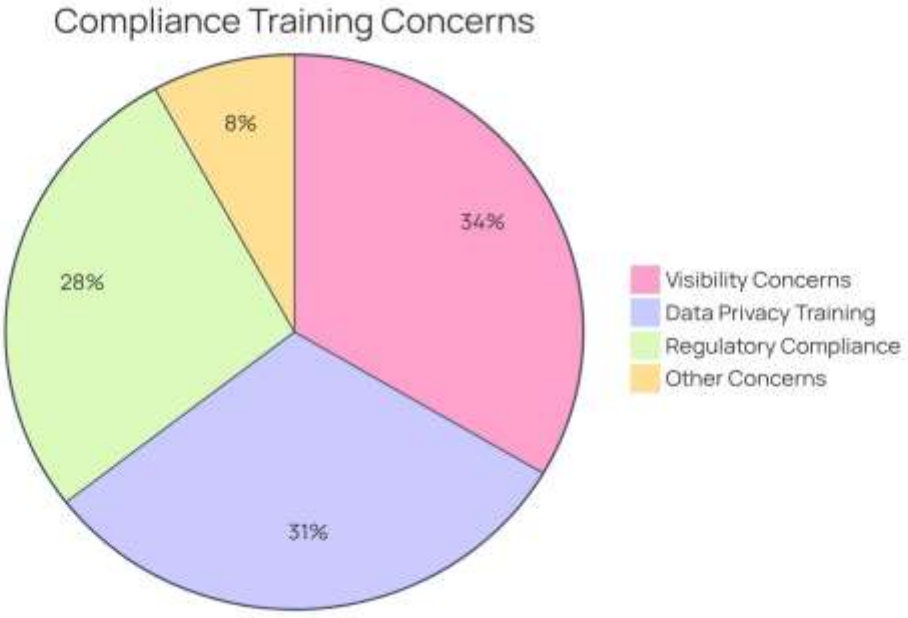

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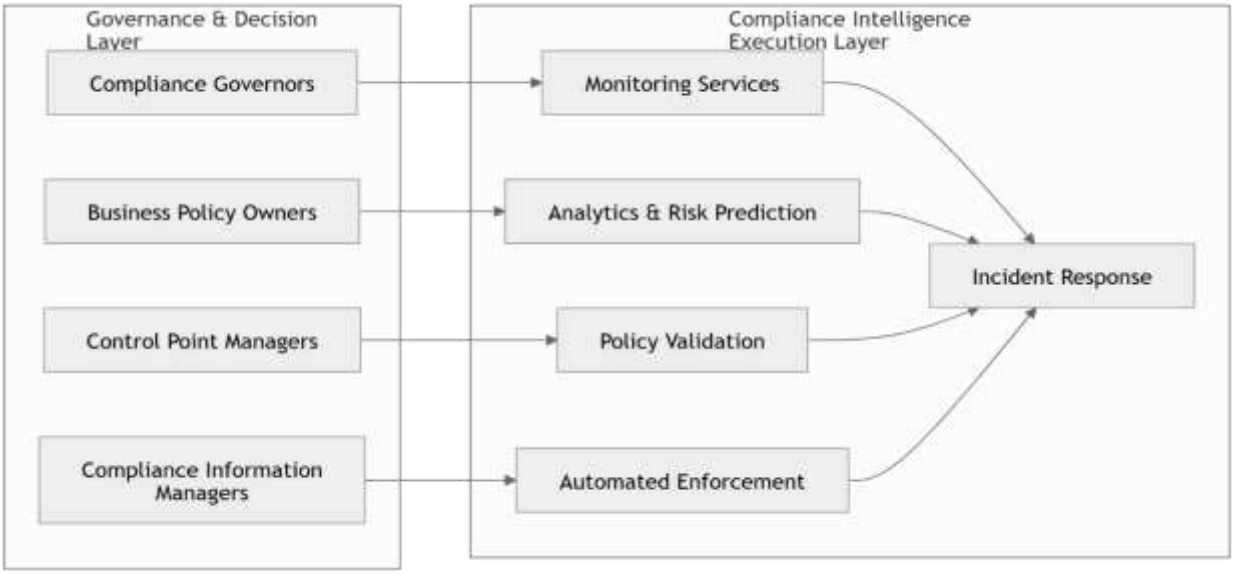

Layered Federated Compliance Intelligence Model

4. Federated Compliance Intelligence in Practice

A stakeholder-centric approach offers an opportunity to pursue vertical and horizontal scaling of requirements engineering for federated compliance intelligence. Stakeholders fulfil defined roles and responsibilities for compliance governance of federated enterprise service ecosystems, within which ecosystem service participants implement corresponding compliance decision-making and intelligence functions. In combination, these services enable the requirements engineering necessary for compliance monitoring, anticipation, detection, prediction, and analysis on an ecosystem-wide basis.

A compliance governor assembles a federated compliance ecosystem and engages a compliance information manager, controlling the ecosystem compliance information, who in turn identifies other relevant compliance information managers. For each enterprise service ecosystem instantiation, actors assume explicit responsibilities, including compliance assurance service and compliance alliance service providers monitoring compliance within their scope and compliance offence champions representing affected parties. Such roles can be filled by the direct actors of compliance offence detection or, for a detected compliance incident, by

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governance stakeholders of the enterprise service ecosystem containing the service offender. Unaffiliated consummators also assume roles, allowing them to provide service alliance services for the enterprise service ecosystem enabling the consignment.

Table 4. Federated Compliance Intelligence Metrics and Validation Parameters

Evaluation Metric	Description	Validation Objective	Measurement Focus
Compliance Detection Accuracy	Ability to detect violations correctly	Monitoring effectiveness	True-positive compliance detection
Event Alignment Efficiency	Synchronization of distributed event data	Data consistency assurance	Cross-service workflow validation
Governance Scalability	Expansion capability across stakeholders	Ecosystem growth support	Horizontal and vertical scaling performance
Response Latency	Time required for compliance remediation	Operational efficiency	Real-time governance responsiveness
Risk Mitigation Effectiveness	Reduction in compliance-related incidents	Security assurance	Violation prevention capability
Service Workflow Conformance	Alignment with regulatory policies	Workflow correctness	Runtime compliance validation
Repository Replication Efficiency	Data consistency across federated nodes	Distributed governance reliability	Synchronization performance

4.1. Stakeholder roles and responsibilities

Past approaches addressing compliance have largely been in an organisation-centric view. However, many organisations are confronted with partnering and joining other organisations to form a federated enterprise. A service offering in such federations is often dependent on services of other partners where the services of others cannot be explicitly controlled. As a result, the service delivery in federated environments introduces the compliance concern. If the compliance concern is not reflected in the service offering, the partner organisation faces the risk of incurring a penalty from a regulatory authority.

In a regulated federal enterprise ecosystem, the compliance governance framework should be defined by the stakeholders external to the federated enterprise, and followed by each participating organisation. Such a framework defines for each participating organisation the regulations and the roles and responsibilities of the stakeholders in relation to the regulatory compliance concern. An extended Directorate of the federation, which includes decision makers from each participating organisation, governs the operations of the federation and acts on behalf of the federation in relation to a regulator. The compliance governance framework that establishes federated compliance intelligence within a regulated federal enterprise ecosystem recognizes the compliance

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perspective of a service whose compliance is governed by a party external to the federated enterprise ecosystem. It identifies the information source required for compliance checking, and defines the stakeholder roles and responsibilities for satisfying the compliance concern in a federated scenario.

5. Scalability Considerations

A federated compliance intelligence architecture is not limited to a single enterprise. It can support multiple enterprises whose compliance governance demands that they extend their compliance policies and compliance governance activities in a collaborative manner. Federated compliance intelligence can horizontally scale in this manner. Another way of horizontally scaling is to distribute compliance governance activities across different compliance governance stakeholders at a specific enterprise. This can be useful in very large enterprises (Bach et al. 2008). For example, instead of development teams conducting self-assessments, it may be more effective to assign actual audits to specific assurance groups who are more qualified for these activities. Furthermore, enterprises are not static entities, and new services are constantly being added. In a well-designed architecture, this vertical scaling

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should simply involve providing the information required at both runtime and during any specific compliance governance activity. Indeed, enterprises often use container-based platforms for their enterprise service ecosystems because of the ease of scaling up and down. Moreover, enterprise compliance policies and compliance governance activities must adapt as new services and capabilities are added.

Guidance is available for horizontal scaling of local compliance intelligence architectures (Tovey et al. 2018). A federated compliance intelligence architecture provides the foundation for similar guidance at a federation level. If some compliance governance stakeholders are located in different geographic locations or time zones, local copies or shared replicas of the compliance intelligence repository can be created for any replication-enabled data sources involved in the federation. Further, the locations of information needed by the different compliance governance stakeholders at any enterprise in the federated constellation need to be considered in order to minimize latency.

Table 5. Compliance Governance Challenges and Federated Solutions

Challenge	Traditional Limitation	Federated Compliance Solution	Expected Benefit
Regulatory Complexity	Manual interpretation of regulations	Automated compliance intelligence	Faster governance adaptation
Multi-Stakeholder Coordination	Fragmented governance processes	Federated layered governance model	Improved collaboration
Scalability Constraints	Centralized governance bottlenecks	Distributed compliance architecture	Elastic enterprise scaling
Compliance Monitoring Delays	Reactive auditing approaches	Real-time event monitoring	Early violation detection
Service Ecosystem Risk	Lack of shared compliance visibility	Shared compliance intelligence repositories	Ecosystem-wide trust
Geographic Distribution	High latency and inconsistent policies	Replicated governance repositories	Low-latency compliance operations
Dynamic Service Growth	Difficulty adapting governance	Runtime scalable compliance services	Flexible service onboarding

5.1. Horizontal and vertical scaling strategies

Horizontal scaling of the operations of the Layered compliance governance model addressing Information Assurance, Security and Privacy perspectives occurs when control points are transferred to other compliance stakeholders. Although ownership transfer of control points is an expected sequence resulting from the transition of a Consumer to a closer position in the Service Ecosystem,

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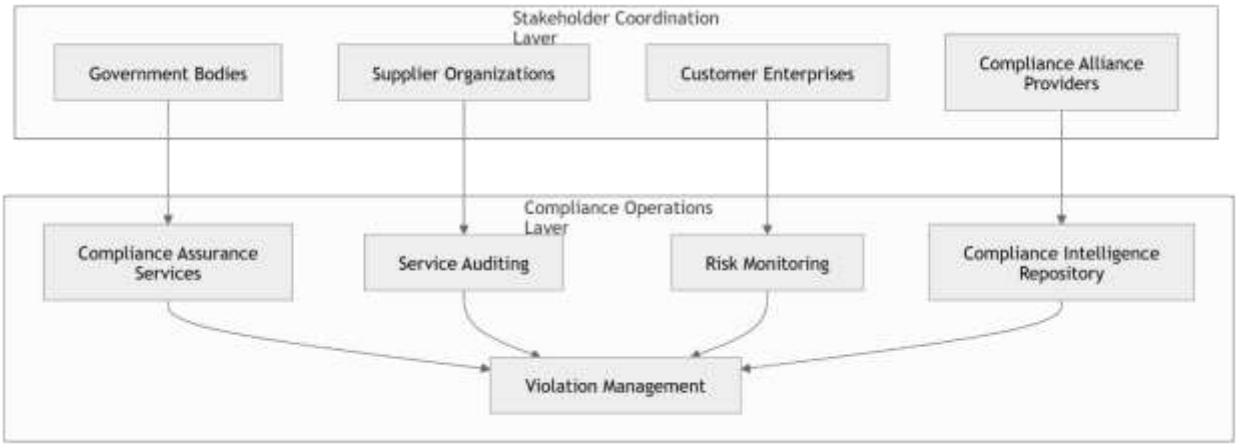
additional transfers may be considered for Service Ecosystems composed of Quality Management stakeholders. Certain Service Ecosystems could have been deployed for novelty or quality considerations, and Consumer Service Providers could use these governance mechanisms for testing, experimentation, performance assurance, or crisis situations.

Vertical scaling of compliance intelligence operations is supported by rapid growth in demand, either sudden burst, prolonged peak or increase in normal level of demand. Demand increase for the ISG perspective increases the number of service components containing Information.



Stakeholder-Centric Compliance Coordination Framework

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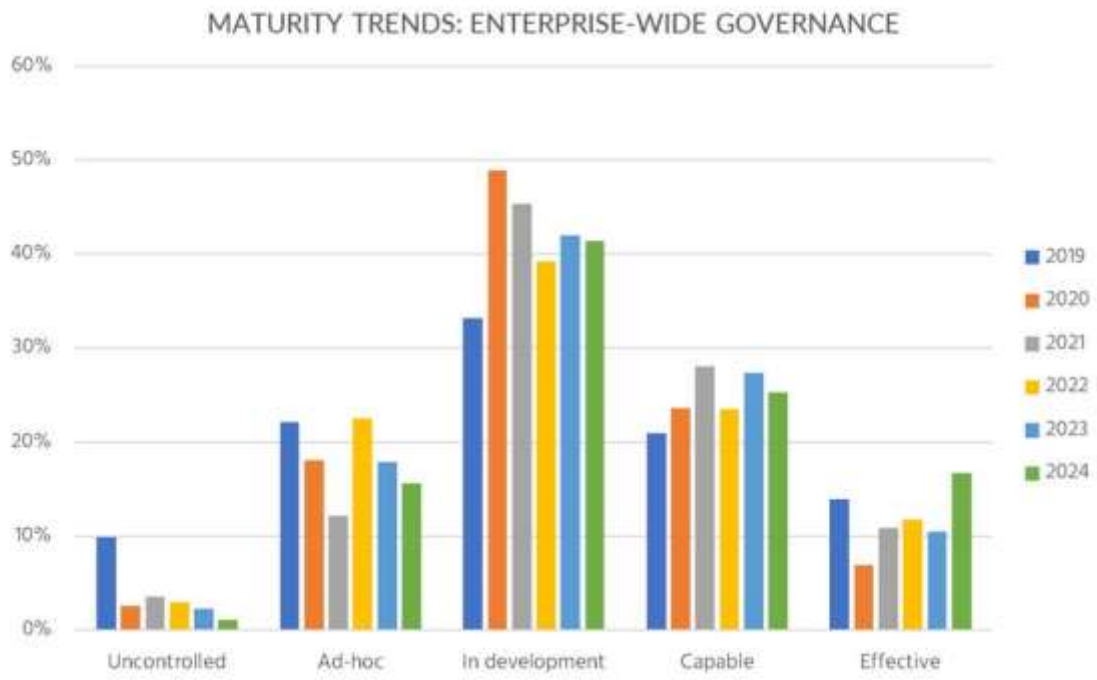

6.Evaluation and Validation

Metrics and benchmarks for validating the applicability and usability of the compliance intelligence architecture and practices in federated enterprise service ecosystems are a conformance-checking approach and experimental results for online compliance monitoring and event data alignment. A lightweight service-event monitor validates event data against formal compliance rules and detects possible violations. An event data alignment method checks whether event data from different service instances can be jointly used for validating compliance properties of data-centric service workflows. Conformance checking for holistic compliance monitoring of data-centric service workflows expresses the correctness of an online compliance monitor, which interacts with a data-centric service workflow for performing event data validation. The core monitor discerns possible service-instance violations as they occur, while the checking services test the fulfilment of compliance properties after the enactment of every service workflow instance. Experimental results evaluate the monitoring and checking services with respect to real-world processes.

Table 6. Enterprise Service Ecosystem Compliance Components

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Component	Description	Role in Governance
Compliance Policies	Rules and standards governing services	Establish governance requirements
Control Point Decision Functions	Runtime compliance validation points	Enforce policy adherence
Compliance Intelligence Services	Analytics and prediction engines	Detect and anticipate risks
Governance Processes	Compliance workflows and procedures	Coordinate ecosystem operations
Service Repositories	Storage of governance artefacts	Maintain compliance records
Stakeholder Communities	Federated collaboration groups	Enable shared governance
Monitoring Services	Continuous compliance tracking	Support runtime assurance
Risk Assessment Modules	Risk identification and prioritization	Enable proactive mitigation

6.1. Metrics and benchmarks

The quantitative evaluation of the applicability and suitability of the proposed concepts and models needs to include metrics for the measurement of the efficiency of federated compliance mechanisms. These mechanisms are typically supported by an underlying business framework and managed by a federated structure, including local federated compliance officers at the business unit level and a central federated compliance officer, organization-wide compliance unit, or business unit compliance service.

The metrics are specific to business frameworks characterized by a cross-business-unit service-oriented architecture, in which the business units are capable of providing services to each other and to customers by using service ecosystems or dynamic service combinations. Events that can influence the qualifications of a service will normally affect first the legal environment of that business unit where the event had happened. Compliance intelligence mechanisms will undertake measures to counteract such an influence. These measures may include, among others, the adaptation of service qualifications and contracts, service production or service consumption intentions, and service process models.

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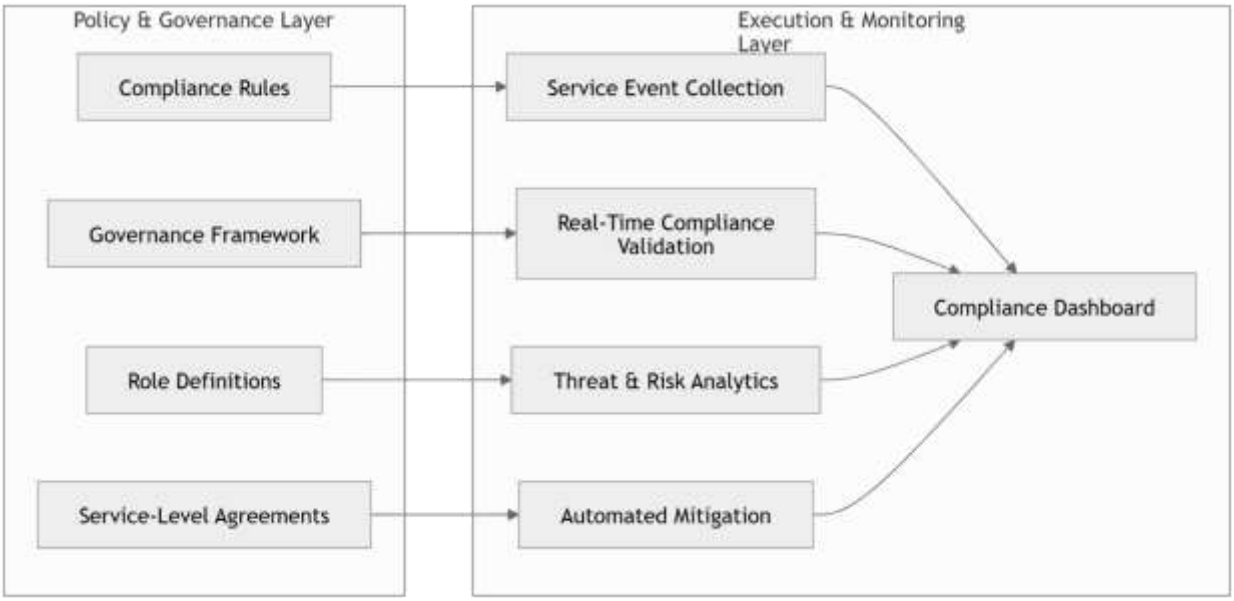

Distributed Compliance Intelligence Workflow

7. Conclusion

In recent years, the newly-emerged collaborative ecosystem service computing paradigm has made it feasible to assemble service functions and workflows in an unanticipated manner and at runtime. Meanwhile, serviced-based systems, a component of the collaborative ecosystem service computing paradigm, have presented serious obstacles because incorporating, configuring, and running compliant services tend to be very hard and labour-intensive manual tasks. However, as proven by the experiences of the enterprise service ecosystem (ESE) and Cloud Computing modelling paradigms, constituting, configuring, matching, enforcing, monitoring, and auditing compliance are very important aspects of using service-based systems in a computationally efficient and effective manner.

A Federated Compliance Intelligence and Governance Theory and Method has been proposed, and its application in Scalable and Sustainable Enterprise Service Ecosystem—realising the compliance management and compliance in a federated and automated way in an enterprise service ecosystem—has been discussed. First, a layered governance model that defines and implements the key aspects, aspects, roles, environments, controls, and features of compliance in the ESE domain has been presented. Then, a Distributed Architecture of the Layered Governance Model has been formulated and can be applied horizontally and vertically. The taken framework, theory, and method enable a new service–component production and computing model with an economy order and scale similar or better than the Service-Oriented Architecture Computing Paradigm.

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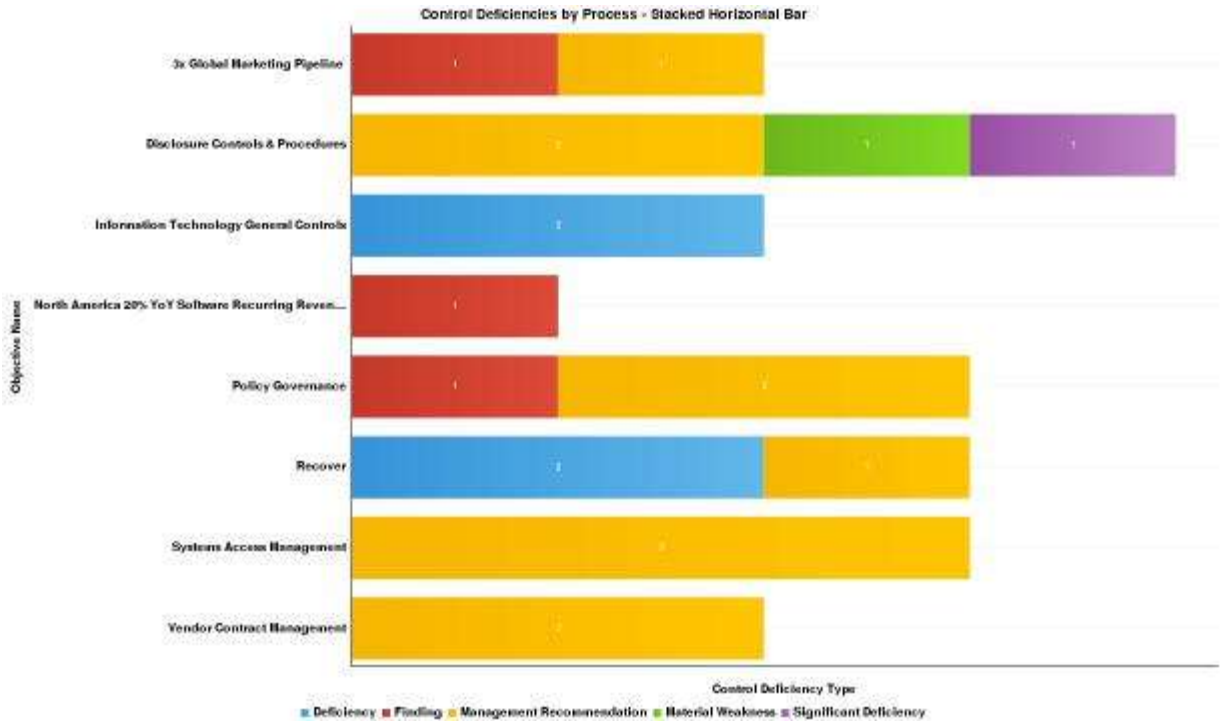

References

1. Aksakalli, I. K., Çelik, T., Can, A. B., & Tekinerdogan, B. (2021). Deployment and communication patterns in microservice architectures: A systematic literature review. Journal of Systems and Software, 180, 111014.
2. Avritzer, A., Ferme, V., Janes, A., Russo, B., van Hoorn, A., Schulz, H., Menasché, D. S., & Rufino, V. (2020). Scalability assessment of microservice architecture deployment configurations: A domain-based approach leveraging operational profiles and load tests. Journal of Systems and Software, 165, 110564.
3. Paleti, S., Burugulla, J. K. R., Pandiri, L., Pamisetty, V., & Challa, K. (2022). Optimizing digital payment ecosystems: AI-enabled risk management, regulatory compliance, and innovation in financial services. Regulatory Compliance. And Innovation In Financial Services (June 15, 2022).
4. Berardi, D., Giallorenzo, S., Mauro, J., & Melis, A. (2022). Microservice security: A systematic literature review. PeerJ Computer Science, 8, e779.
5. Challagidad, P. S., & Birje, M. N. (2020). Multi-dimensional dynamic trust evaluation scheme for cloud environment. Computers & Security, 91, 101722.

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6. Chandramouli, R., Butcher, Z., & Chetal, A. (2021). Attribute-based access control for microservices-based applications using a service mesh. NIST.
7. Han, C., Kim, T., Lee, W., & Shin, Y. (2024). S-ZAC: Hardening access control of service mesh using Intel SGX for zero trust in cloud. Electronics, 13(16), 3213.
8. Hassan, S., Bahsoon, R., & Buyya, R. (2022). Systematic scalability analysis for microservices granularity adaptation design decisions. Software: Practice and Experience, 52(6), 1378–1401.
9. Davuluri, P. S. L. (2023). AI-Augmented Sanctions Screening: Enhancing Accuracy and Latency in Real Time Compliance Systems. AI-Augmented Sanctions Screening: Enhancing Accuracy and Latency in Real Time Compliance Systems (December 15, 2023).
10. Haindl, P., Kochberger, P., & Sveggen, M. (2024). A systematic literature review of inter-service security threats and mitigation strategies in microservice architectures. IEEE Access, 12, 90252–90286.
11. Jiao, H., Wang, X., & Ding, W. (2020). Service oriented cloud computing trusted evaluation model. Journal of Information Processing Systems, 16(6), 1281–1292.
12. Lenarduzzi, V., Lomio, F., & Saarimäki, N. (2020). Does migrating a monolithic system to microservices decrease the technical debt? Journal of Systems and Software, 169, 110710.
13. Minna, F., & Massacci, F. (2023). SoK: Run-time security for cloud microservices. Computers & Security, 127, 103119.
14. Nasab, A. R., Shahin, M., Liang, P., Basiri, M. E., Hoseyni Raviz, S. A., Khalajzadeh, H., Waseem, M., & Naseri, A. (2021). Automated identification of security discussions in microservices systems: Industrial surveys and experiments. Journal of Systems and Software, 181, 111046.
15. Mukesh, A., & Aitha, A. R. (2021). Insurance Risk Assessment Using Predictive Modeling Techniques. International Journal of Emerging Research in Engineering and Technology, 2(4), 68-79.
16. Nasab, A. R., Shahin, M., Hoseyni Raviz, S. A., Liang, P., Mashmool, A., & Lenarduzzi, V. (2023). An empirical study of security practices for microservices systems. Journal of Systems and Software, 198, 111563.
17. Pereira-Vale, A., Fernandez, E. B., Monge, R., Astudillo, H., & Márquez, G. (2021). Security in microservice-based systems: A multivocal literature review. Computers & Security, 103, 102200.
18. Rezaei Nasab, A., Shahin, M., Liang, P., & colleagues. (2023). Security practices and challenges in microservice systems. Journal of Systems and Software, 198, 111563.
19. Schneider, S., Diaz Ferreyra, N. E., Simhandl, G., Zdun, U., & Scandariato, R. (2022). Towards a security benchmark for the architectural design of microservice applications. In Proceedings of the 17th International Conference on Availability, Reliability and Security.
20. Inala, R. (2023). AI-powered investment decision support systems: Building smart data products with embedded governance controls. Journal for ReAttach Therapy and Developmental Diversities, 6(10), 2251-2266.
21. Schneider, S., & Scandariato, R. (2023). Automatic extraction of security-rich dataflow diagrams for microservice applications written in Java. Journal of Systems and Software, 202, 111722.
22. Söylemez, M., Tekinerdogan, B., & Tarhan, A. K. (2024). Microservice reference architecture design: A multi-case study. Software: Practice and Experience, 54(1), 58–84.
23. Solans, D., Pérez Hernández, M. de los S., & Muntés Mulero, V. (2020). Graph-based root cause analysis for service-oriented and microservice architectures. Journal of Systems and Software, 159.
24. Waseem, M., Liang, P., & Shahin, M. (2020). A systematic mapping study on microservices architecture in DevOps. Journal of Systems and Software, 170, 110798.

25. Zhong, C., & Zhang, H. (2022). Impacts, causes, and solutions of architectural smells in microservices: An industrial investigation. Software: Practice and Experience.
26. Raj, V., & Ravichandra, S. (2022). A service graph based extraction of microservices from monolith services of service-oriented architecture. Software: Practice and Experience, 52(7), 1661–1678.
27. Rezaei Nasab, A., Shahin, M., Liang, P., & colleagues. (2021). Security discussions and security decision-making in microservices systems. Journal of Systems and Software, 181, 111046.
28. Minna, F., Massacci, F., & colleagues. (2023). Runtime security and continuous trust evaluation for cloud microservices. Computers & Security, 127, 103119.
29. Hassan, S., Bahsoon, R., & Buyya, R. (2022). Scalability and granularity adaptation in microservice architectures. Software: Practice and Experience, 52(6), 1378–1401.
30. Soldani, J., Forti, S., & Brogi, A. (2024). Explaining microservices' cascading failures from their logs. Software: Practice and Experience, 54, 809–828.
31. Gottimukkala, V. R. R. (2024). Federated Learning Approaches for Fraud Detection in International Payment Systems. https://www. jisem-journal. com/download/118_JISEM. pdf.
32. Hu, K., Xu, M., Ye, K., & Xu, C. (2024). LSRAM: A lightweight autoscaling and SLO resource allocation framework for microservices based on gradient descent. Software: Practice and Experience.
33. Schneider, S., Scandariato, R., & colleagues. (2024). Security analysis and continuous assurance for microservice architectures. Journal of Systems and Software.
34. Avritzer, A., Ferme, V., Janes, A., Russo, B., van Hoorn, A., Schulz, H., Menasché, D. S., & Rufino, V. (2020). Operational-profile-based scalability analysis of microservice deployment configurations. Journal of Systems and Software, 165, 110564.
35. Xiao, S. (2022). SoK: Context and risk aware access control for zero trust systems. Security and Communication Networks, 2022, 7026779.
36. He, H., et al. (2022). A survey on zero trust architecture: Challenges and future trends. Wireless Communications and Mobile Computing, 2022, 6476274.
37. Firdous, N. S., Shah, S. W., Shaghaghi, A., Anwar, A., & Iqbal, M. (2022). Zero Trust Architecture (ZTA): A comprehensive survey. IEEE Access, 10.
38. Palavali, D. R., & Pothireddy, S. (2023). Policy everywhere: Zero trust API security through embedded enforcement in microservice meshes. International Journal of Information and Electronics Engineering, 13(4).
39. Alevizos, L., Ta, V. T., & Eiza, M. H. (2021). Augmenting zero trust architecture to endpoints using blockchain: A state-of-the-art review. arXiv.
40. Han, C., Kim, T., Lee, W., & Shin, Y. (2024). Zero-trust access control and security enforcement for cloud service-mesh environments. Electronics, 13(16), 3213.