Transport

EXTENDING THE STRATEGIC DATA ALIGNMENT FRAMEWORK (SDAF): POLICY AND REGULATORY IMPLICATIONS OF BIG DATA GOVERNANCE IN CASPIAN BASIN PORTS

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Abstract. The Caspian Basin is becoming an essential hub in the Belt and Road Initiative (BRI) and the Trans-Caspian International Transport Route (TITR), linking Asian and European markets. While physical infrastructure in the region has advanced, regulatory and institutional frameworks for Big Data governance remain fragmented. This paper investigates the policy and regulatory implications of Big Data governance in Azerbaijan, Kazakhstan, Russia, Turkmenistan, and Iran, focusing on seaports as digital gateways to global supply chains. Through comparative policy analysis, cross-case coding, and benchmarking against international frameworks such as those of the European Union, the International Maritime Organization, and the World Trade Organization, four persistent challenges are identified: fragmented regulations, weak compliance, institutional limitations, and cybersecurity vulnerabilities. The study extends the Strategic Data Alignment Framework (SDAF) – originally designed to align corporate strategies with Big Data governance – into the policy-regulatory sphere. Findings show that regulatory convergence can serve as a strategic resource for Caspian ports. A five-point roadmap is proposed to promote harmonization, strengthen cybersecurity, and enhance digital corridor integration.

Keywords: *Big Data Governance; Caspian Basin Ports; Belt and Road Initiative (BRI); Trans-Caspian International Transport Route (TITR); Strategic Data Alignment Framework (SDAF); Regulatory Convergence; Maritime Cybersecurity; Port Community Systems.*

I. Introduction

The Caspian Basin has gained increasing importance as a strategic transport corridor, particularly within the framework of the Belt and Road Initiative (BRI) and the Trans-Caspian International Transport Route (TITR). Ports such as Baku in Azerbaijan, Aktau and Kuryk in Kazakhstan, and Astrakhan in Russia serve as gateways for Eurasian trade, connecting inland supply chains to global maritime networks. In parallel with infrastructure investments, effective digital governance has become essential to ensure interoperability, efficiency, and resilience of port operations [1], [2].

Despite this progress, the regulatory and institutional frameworks governing Big Data remain fragmented across the Caspian states. Different national strategies often lead to misalignment in data-sharing practices, inconsistent compliance with international standards, and vulnerabilities in cybersecurity systems [3 – 5]. These gaps hinder the development of trusted digital corridors and reduce the competitiveness of Caspian ports in comparison with their European and East Asian counterparts.

This paper addresses these gaps by extending the **Strategic Data Alignment Framework**—originally developed to align corporate strategies with Big Data governance [6] and further operationalized in practice [7] – into the policy and regulatory domain. By applying the SDAF lens at the state and regional level, the study investigates how regulatory convergence can function as a strategic resource for regional competitiveness.

The purpose of this research is to analyze the policy and regulatory implications of Big Data governance for Caspian Basin ports and propose a roadmap toward harmonization. The study applies comparative policy analysis and cross-case coding, benchmarked against the European Union's *Digital Transport and Logistics Forum (DTLF)*, the International Maritime Organization's *Facilitation (FAL) Convention*, and the World Trade Organization's digital trade principles.

The central research question is: **How can harmonized Big Data governance frameworks enhance the competitiveness and global integration of Caspian Basin ports?**

By addressing this question, the paper contributes to both theory and practice. Theoretically, it extends SDAF to the policy-regulatory domain, while also framing regulatory convergence as a *valuable, rare, inimitable, and non-substitutable (VRIN)* resource under the Resource-Based View [8]. Practically, it provides a five-point roadmap for regional cooperation, aligning Caspian ports more closely with international digital trade standards.

II. Related Work

Big Data Governance in Ports

Big Data governance has become a central enabler of efficiency, competitiveness, and innovation in maritime transport. Studies emphasize that advanced data analytics and governance frameworks enhance decision-making, optimize resource allocation, and support business model innovation [9]. The digital transformation of maritime transport demonstrates how ports that successfully integrate Big Data into operations can achieve greater sustainability, agility, and resilience [10].

Comparative Governance Models

Global policy frameworks illustrate the benefits of regulatory harmonization. The European Union's Digital Transport and Logistics Forum (DTLF) promotes electronic documentation and interoperability across borders [11]. The International Maritime Organization's Facilitation (FAL) Convention similarly seeks to streamline reporting formalities and reduce data bottlenecks in shipping. Despite these efforts, emerging markets still face barriers including weak institutional capacity, siloed regulations, and inconsistent compliance [8].

Caspian Basin Challenges

The Caspian Basin presents unique institutional and regulatory complexities. Azerbaijan has adopted digital trade policies to strengthen its role as a logistics hub [1], while Kazakhstan's Aktau and Kuryk ports highlight the opportunities and vulnerabilities of relying on BRI digital platforms [2]. At the same time, smaller ports across the region face resource constraints and lack harmonized governance mechanisms [3], [4]. Concerns over data sovereignty further complicate cooperation, particularly in Russia and Iran [4].

Theoretical Framework: SDAF and RBV

The Strategic Data Alignment Framework was introduced by Alekberli [6] and Alekberli and Haussmann [7]. Alekberli [6] as a model to align corporate strategies with Big Data governance, addressing the gap between strategic intent and data management capabilities. This framework was further operationalized through practical guidelines by from Alekberli [6] and Alekberli and Haussmann [7], demonstrating its applicability to organizational settings in Caspian Basin ports. Building on this foundation, the present study extends SDAF into the policy-regulatory domain, exploring how alignment across states can generate systemic value.

From a theoretical standpoint, the Resource-Based View (RBV) provides additional grounding. Regulatory convergence is conceptualized here as a strategic asset that meets the VRIN criteria: valuable, rare, inimitable, and non-substitutable [8]. This perspective underscores the importance of harmonized governance as a driver of sustainable competitive advantage in regional port systems.

III. Methods (Research Methodology)

Research Design

This study adopts a **qualitative comparative policy analysis** to examine Big Data governance frameworks in the Caspian Basin. The design was chosen because the research question concerns institutional and regulatory alignment, which requires contextual interpretation of laws, strategies, and frameworks rather than purely quantitative indicators [12].

Data Sources

Primary sources of data included:

- **National strategies and policies**: Azerbaijan's Digital Trade Strategy, Kazakhstan's Digital Kazakhstan program, Russia's Digital Economy framework, Iran's ICT Roadmap, and Turkmenistan's transport modernization strategy [13–17].
- **Regional agreements**: TRACECA policy documents and Caspian Economic Forum resolutions [18].
- **International standards**: The EU's *Digital Transport and Logistics Forum (DTLF)*, the IMO's *Facilitation (FAL) Convention*, and WTO digital trade principles [19].

Secondary sources included peer-reviewed literature (2020–2024) addressing digitalization, port governance, and regional integration challenges [6], [7], [20].

Data Analysis

Policies were examined using **thematic coding** [21]. The following categories were applied:

1. **Data-sharing and interoperability**
2. **Compliance with international standards**
3. **Cybersecurity and data protection**
4. **Institutional cooperation and governance capacity**

Cross-case coding enabled comparison across Azerbaijan, Kazakhstan, Russia, Iran, and Turkmenistan [13–17].

Benchmarking

Each country's policies were benchmarked against international frameworks to measure the degree of alignment. EU DTLF served as the baseline for interoperability and electronic documentation; IMO FAL for facilitation standards; and WTO digital trade rules for transparency and cross-border exchange [13–17].

Validation

To enhance credibility, findings were reviewed with experts from Azerbaijan's Baku International Sea Trade Port and Kazakhstan's Aktau Port. Feedback was incorporated to refine coding and contextual interpretations [13–17].

Triangulation across national, regional, and international sources ensured reliability.

Theoretical Integration

The analysis was guided by the **Strategic Data Alignment Framework**, initially developed by Alekberli [6] and extended into practice by Alekberli and Haussmann [7]. Here, SDAF is adapted to assess policy-regulatory alignment, providing a structured lens for evaluating whether governance practices align with strategic trade objectives.

IV. Results

Regulatory Fragmentation

Comparative analysis revealed that each Caspian state has developed its own national digital strategies, but these remain largely **siloed**. Azerbaijan emphasizes trade facilitation and digital customs integration, Kazakhstan focuses on embedding BRI platforms through *Digital Kazakhstan*, Russia enforces sovereignty-driven data policies, while Iran and Turkmenistan prioritize national security and state control. The absence of a **regional governance mechanism** prevents harmonization, causing duplication of reporting, increased transaction costs, and delays in port logistics [4], [22].

Weak Compliance with International Standards

Benchmarking against international frameworks demonstrated **partial and inconsistent adoption** of the IMO's *Facilitation (FAL) Convention* and the EU's *Digital Transport and Logistics Forum (DTLF)*. Azerbaijan has made progress with digital customs systems but remains limited in cross-border interoperability [23]. Kazakhstan has adopted select electronic documentation systems but lacks harmonization with EU standards [23]. Russia enforces localized compliance that diverges from international expectations, while Iran and Turkmenistan have yet to adopt structured compliance mechanisms [23].

Institutional Capacity Gaps

Small and medium-sized ports in the Caspian Basin continue to struggle with **institutional weaknesses** [23–25]. Case coding revealed limited digital expertise, insufficient budgets, and outdated IT systems. As a result, national strategies are not fully implemented at the operational level [3], [5]. Institutional inertia further slows adaptation to international standards, reducing the ability of Caspian ports to integrate into global trade networks.

Cybersecurity Vulnerabilities

Cybersecurity frameworks across Caspian states are **unevenly enforced**, creating risks for port operations. Russia prioritizes digital sovereignty, but its closed architecture limits cross-border data exchange. Azerbaijan and Kazakhstan have begun adopting international cyber norms, yet enforcement remains weak. Iran and Turkmenistan have security-centric systems that restrict cooperation. These fragmented approaches leave the region vulnerable to **cyberattacks, ransomware, and data breaches** in critical maritime infrastructure [26], [27].

Case Study Insights

- **Baku International Sea Trade Port (Azerbaijan):** Positioned as a smart logistics hub with growing investment in port community systems (PCS). However, lack of regional harmonization reduces its potential as a *digital corridor leader* [1].
- **Aktau and Kuryk Ports (Kazakhstan):** Benefit from integration with BRI trade corridors but remain **dependent on Chinese digital platforms**, creating sovereignty concerns and limiting interoperability with EU systems [2].
- **Astrakhan Port (Russia):** Operates under sovereignty-first governance, prioritizing national control over interoperability. This approach undermines cross-border data-sharing and weakens Russia's role in regional digital integration [4].

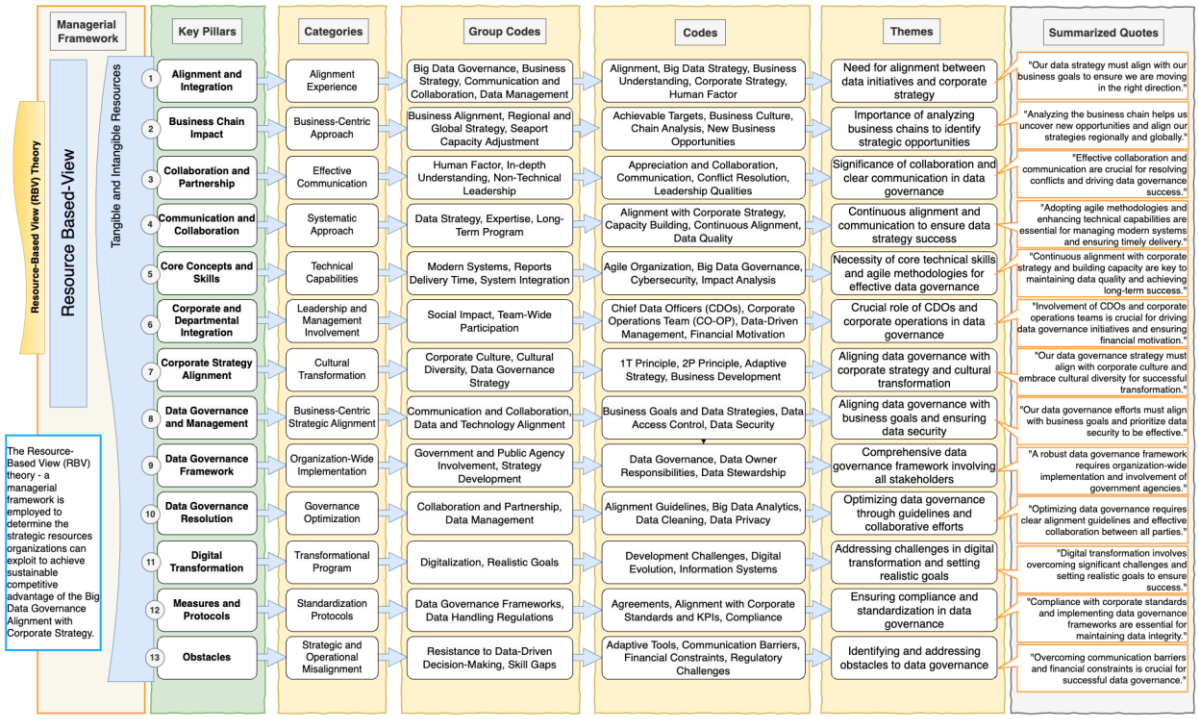
V. Discussion

SDAF as a Policy-Regulatory Framework

The results confirm that SDAF offers a robust foundation for assessing regulatory convergence in the Caspian Basin. Originally introduced by Alekberli [6] and Alekberli and Haussmann [7]. to align corporate strategies with Big Data governance, and operationalized through applied guidelines by from Alekberli and Alekberli and Haussmann, the framework is extended here to the **policy and regulatory domain** [6], [7].

SDAF emphasizes four interdependent dimensions: **strategic alignment, governance mechanisms, institutional cooperation, and compliance standards**. When applied at the state and regional level, these dimensions highlight why Caspian states experience persistent fragmentation. Strategic priorities often diverge across countries, governance rules are inconsistent, institutions lack resources, and compliance with international standards remains partial [6], [7].

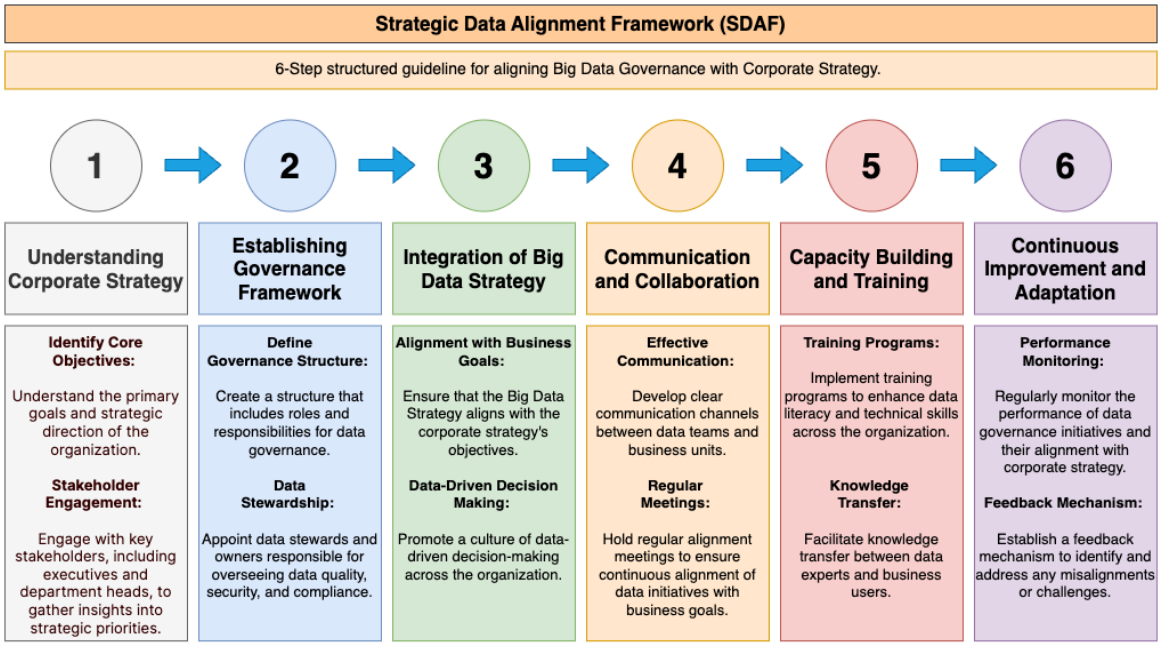
Structured Strategic Data Alignment Framework.



- Adapted from Alekberli and Alekberli and Haussmann [6], [7]. The framework illustrates how strategic alignment, governance mechanisms, institutional cooperation, and compliance standards interact when applied beyond the corporate level into regional policy contexts.

Strategic Data Alignment Framework extended to policy and regulatory governance in the Caspian Basin.

Six-step SDAF guideline for aligning corporate strategy with Big Data governance



- Adapted from Alekberli and Alekberli and Haussmann [6], [7]. The guideline illustrates six sequential steps for implementing the Strategic Data Alignment Framework (SDAF): (1) defining strategic objectives, (2) mapping data governance priorities, (3) establishing regulatory and compliance mechanisms, (4) integrating institutional cooperation, (5) monitoring performance through digital metrics, and (6) continuous alignment and feedback. While originally developed for corporate environments, the model is extended here to the policy-regulatory domain of the Caspian Basin, providing a structured pathway for harmonized digital governance.

Structured Strategic Data Alignment guideline

This figure illustrates how SDAF provides a structured pathway from fragmented strategies to harmonized governance, emphasizing alignment as the bridge between national policies and global digital trade standards.

RBV Lens: Regulatory Convergence as a Strategic Resource

The Resource-Based View (RBV) provides additional theoretical grounding. Regulatory convergence meets the VRIN criteria [7], [8]:

- **Valuable**: It reduces costs, accelerates cargo clearance, and improves resilience.
- **Rare**: Few regional corridors achieve true regulatory harmonization.
- **Inimitable**: Convergence requires long-term cooperation and path dependency, making it difficult to replicate.
- **Non-substitutable**: No technical substitute exists for harmonized policy frameworks.

Thus, regulatory convergence can be conceptualized as a **strategic intangible resource**, enabling Caspian ports to achieve sustainable competitive advantage.

Policy Implications

The study's findings have significant implications for policymakers and regional stakeholders:

1. **Regional Coordination:** Establishing a Caspian Digital Port Forum would institutionalize dialogue and align digital strategies.
2. **Port Community Systems (PCS):** A regional PCS could reduce duplication and improve interoperability across borders.
3. **International Alignment:** Adoption of EU DTLF standards, IMO FAL requirements, and WTO digital trade principles would strengthen global trust.
4. **Cybersecurity Harmonization:** Shared frameworks for maritime cybersecurity would reduce vulnerabilities and enhance resilience.
5. **Pilot Cooperation Projects:** Joint initiatives—such as digital corridor pilots between Azerbaijan and Kazakhstan—would demonstrate feasibility and build momentum for broader reforms.

Together, these policy actions would not only reduce fragmentation but also position Caspian ports as **trusted digital corridors** linking the Belt and Road Initiative with the EU's TEN-T system.

Conclusion

This study examined the **policy and regulatory implications of Big Data governance** in the Caspian Basin, focusing on ports as strategic nodes within the Belt and Road Initiative (BRI) and the Trans-Caspian International Transport Route (TITR). Despite growing investments in physical infrastructure, the findings show that digital governance across the region remains fragmented. Divergent national policies, inconsistent compliance with international standards, limited institutional capacity, and cybersecurity vulnerabilities hinder the ability of Caspian ports to function as integrated digital corridors.

Theoretically, the paper makes two major contributions. First, it extends the **Strategic Data Alignment Framework** —originally developed to align corporate strat—into the policy and regulatory domain. Second, it reframes **regulatory convergence as a strategic VRIN resource** under the Resource-Based View [8], highlighting its potential to deliver sustainable competitive advantage for regional ports [6], [7].

Practically, the study proposes a **five-point roadmap**:

1. Establishing a Caspian Digital Port Forum.
2. Developing a regional Port Community System (PCS).
3. Aligning policies with EU, IMO, and WTO standards.
4. Implementing harmonized cybersecurity frameworks.
5. Launching pilot cooperation projects.

If adopted, these measures would position Caspian ports as **trusted digital corridors**, strengthening their integration into global supply chains and enhancing resilience in the face of geopolitical and technological challenges.

Future research should expand this analysis by incorporating **quantitative performance metrics**, exploring **comparisons with other regional corridors** such as the Black Sea or Adriatic, and conducting **longitudinal studies** to track the effectiveness of governance reforms over time.

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