**Cloud-Based AI Solutions for Real-Time Monitoring of E-commerce Compliance and Risk**

**Abstract**

*This study investigates the integration of cloud-based Artificial Intelligence (AI) solutions for real-time compliance and risk monitoring in e-commerce platforms, addressing the pressing need for scalable oversight as transaction volumes and complexities surge. Utilizing the Olist Brazilian E-commerce dataset, which captures diverse vendor behaviors representative of both large and small enterprises, the research adopts a multi-phase quantitative approach. Descriptive statistics were used to establish baseline transactional patterns, while anomaly detection via Isolation Forest identified outliers indicative of potential compliance breaches. Logistic regression was employed to evaluate the relationship between vendor behaviors such as delivery delays, order cancellations, and product quantities and customer dissatisfaction, illuminating the multifactorial nature of compliance risks that cannot be attributed to single variables alone. Principal Component Analysis (PCA) distilled critical factors essential for effective monitoring. To ensure the robustness and generalizability of the proposed AI framework, 10-fold cross-validation was conducted, achieving an average predictive accuracy of 95.3%. Expert validation through Likert-scale surveys further confirmed the practical feasibility of the framework. The study demonstrates that combining anomaly detection, behavioral modeling, and dimensionality reduction within a cloud-based infrastructure enables dynamic and reliable compliance oversight. Recommendations include standardizing AI integration guidelines, strengthening workforce skills in AI deployment, and reinforcing data governance frameworks to promote scalable, secure, and effective compliance monitoring in rapidly evolving e-commerce environments.*

**Keywords: cloud-based AI, compliance monitoring, anomaly detection, Principal Component Analysis, e-commerce risk management.**

**1. Introduction**

The accelerated expansion of e-commerce has introduced increasingly complex challenges related to regulatory compliance and risk mitigation in digital transactions (Putrevu & Mertzanis, 2023). Traditional methods of compliance monitoring, while historically foundational, are proving inadequate in addressing the evolving dynamics of online commerce (Xi, 2024). According to Javaid et al. (2022), the pace, and volume of digital interactions necessitate technologically advanced solutions capable of real-time responsiveness and adaptive functionality (Adigwe et al., 2024).

Cloud-based Artificial Intelligence (AI) technologies have emerged as strategic instruments for resolving these challenges, primarily through their capacity to handle extensive datasets with speed and precision (Banerjee, 2024). Bauskar (2025) posits that by leveraging the elastic scalability of cloud infrastructure, AI systems can efficiently detect anomalies, forecast potential risks, and enforce compliance standards across heterogeneous platforms. This convergence of AI and cloud computing not only streamlines operational procedures but also reinforces the security architecture and reliability of e-commerce ecosystems (Singh et al., 2024; Arigbabu et al., 2024).

According to Wang and Yang (2025), multiple case examples from industry leaders underscore the practicality and effectiveness of such integrations. For instance, Mastercard utilizes AI algorithms to oversee over 159 billion transactions annually, thereby enhancing its fraud detection mechanisms and minimizing the incidence of false positives (Driver, 2025). Similarly, Watson & McCowan (2025) reports that Ernst & Young’s Risk AI Hub, an AI-driven centralized control mechanism, provides real-time surveillance and evaluation of third-party risks, which strengthens organizational resilience and fortifies cybersecurity protocols.

In the domain of compliance automation, Wang and Yang (2025) introduced a machine learning-based compliance framework that not only reduced processing time from seven days to 1.5 days but also elevated accuracy levels from 78% to 93% within a prominent securities firm. This empirical evidence highlights the utility of AI in expediting compliance operations while improving reliability metrics. Additionally, Khan et al. (2021) state that iHealth’s adoption of Amazon Web Services (AWS) Cloud, combined with a blockchain-supported architecture, significantly curtailed vulnerability exposure and accelerated incident response rates, illustrating the integrative potential of AI and blockchain in enhancing vendor risk oversight.

Madanchian, (2024) further contend that broader market analytics reflect the growing influence of AI within e-commerce infrastructure. As of 2025, the global valuation of the AI-enabled e-commerce sector stands at approximately $8.65 billion, with projections suggesting growth to $22.60 billion by 2032 at a compound annual growth rate (CAGR) of 14.6% (Jason, 2024). Approximately 51% of e-commerce enterprises have integrated AI functionalities into their systems, with AI-driven personalization contributing to a 25% uplift in sales performance and a 15% increase in customer-generated reviews (Mayer et al., 2025).

Despite these advancements, Robertson et al. (2021) argue that the absence of standardized frameworks continues to impede the systematic implementation of cloud-based AI solutions. Concerns related to data security, interoperability, and ambiguous regulatory directives hinder broader adoption across diverse e-commerce platforms (Salako et al., 2024). Furthermore, while models from entities such as Mastercard and EY illustrate effective AI assimilation, Kusuma (2022) asserts that these cases are often context-specific and may lack generalizability across varying operational configurations and jurisdictional mandates. Consequently, the heterogeneity of e-commerce operations necessitates the development of flexible, scalable frameworks that can accommodate structural diversity while maintaining compliance integrity and mitigating risk exposure (Kusuma, 2022).

Therefore, there is a pressing need for research that not only examines existing AI integration practices but also develops a standardized and adaptable framework to guide e-commerce businesses in effectively deploying cloud-based AI solutions for real-time compliance and risk monitoring. Such research would bridge the gap between theoretical models and practical applications, facilitating broader adoption and enhancing the overall integrity of e-commerce operations.

This study aims to develop a practical and standardized framework for integrating cloud-based AI solutions into e-commerce platforms to support real-time compliance and risk monitoring. By drawing insights from real-world case studies, the research seeks to bridge the gap between theoretical AI integration models and their practical application in diverse e-commerce environments, pursuing the following steps:

 1. To critically examine how cloud-based AI technologies are currently used for compliance and risk monitoring across leading e-commerce platforms.

 2. To identify the practical challenges and enabling factors affecting the integration of AI solutions into existing e-commerce systems.

 3. To design a standardized and adaptable framework for integrating AI into e-commerce platforms for real-time compliance and risk oversight.

 4. To validate the proposed framework using insights from selected e-commerce case studies and expert feedback.

As digital commerce continues to grow at an unprecedented rate, the consequences of non-compliance ranging from financial penalties to reputational damage can be severe. Moreover, as e-commerce platforms scale globally, they face increasingly complex and fragmented regulatory environments that demand dynamic and scalable oversight mechanisms. Cloud-based AI solutions, by design, offer the elasticity and intelligence required to meet these demands. However, without a unified framework to guide their integration and governance, organizations risk deploying systems that are either underutilized or misaligned with compliance standards.

**2. Literature** **Review**

Artificial Intelligence (AI) has become essential in advancing compliance and risk monitoring mechanisms across sectors, with particular efficacy in e-commerce. A notable application of AI is in fraud detection and transaction surveillance. According to Villano (2025), Mastercard has implemented AI-based systems capable of analyzing up to 160 billion transactions annually, assigning real-time risk scores to flag potentially fraudulent activities within milliseconds. The company’s Decision Intelligence platform utilizes behavioural biometrics and interaction pattern analysis to detect transactional anomalies, thereby decreasing false positives and strengthening fraud mitigation efforts.

In the domain of third-party risk oversight, Watson & McCowan (2025) posits that Ernst & Young (EY) has developed the RiskAI Hub, an AI-powered centralized control infrastructure intended to manage third-party risks at a global scale. This system supports continuous assessment of regulatory and compliance risks, enhancing operational resilience and cybersecurity by enabling rapid data analysis and facilitating preemptive risk mitigation strategies (Kolade et al., 2025).

Blockchain has also been synergistically integrated with AI to bolster transparency and compliance monitoring in vendor ecosystems (Joseph, 2024; Rane et al., 2023). Khan et al., (2021) illustrate this through the case of iHealth’s migration to AWS Cloud, where the deployment of a blockchain-enhanced framework resulted in fewer system vulnerabilities and accelerated incident response. Leveraging smart contracts, the framework ensures transparency and real-time tracking of compliance and security protocols, thereby fortifying organizational defences against emerging cyber threats (Obioha-Val et al., 2025; Hasan, 2024).

Furthermore, Olabanji et al., (2024) reports that machine learning technologies are being employed to automate compliance processes in high-volume digital settings. Wang and Yang (2025), for instance, introduced a machine learning-based compliance model that reduced processing time from seven days to 1.5 days and improved accuracy from 78% to 93% in a major securities firm. This implementation, which incorporates tools such as BERT-based document analysis and anomaly detection algorithms, exemplifies the capacity of AI to optimize compliance workflows and refine decision-making.

These varied applications collectively demonstrate how AI technologies are reshaping compliance and risk management practices by increasing procedural efficiency, promoting regulatory conformity, and preemptively addressing threats in e-commerce and related domains (Olabanji et al., 2024; Mbah, 2024).

**Cloud Computing Infrastructure and Its Role in AI Integration**

Cloud computing infrastructure serves as the foundational architecture for deploying Artificial Intelligence (AI) solutions aimed at real-time compliance and risk monitoring within e-commerce platforms (Olabanji et al., 2024). According to Borra (2024), leading providers such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) offer expansive environments that support the building, training, and deployment of AI applications with minimal latency and high computational throughput. Services such as AWS SageMaker, Azure Machine Learning, and Google’s Vertex AI provide modular toolkits that allow for scalable model training and inference (Sakshi Waghmare, 2024). These platforms further support real-time data ingestion and processing through technologies like Amazon Kinesis, Azure Stream Analytics, and Google Cloud Dataflow, while their API-based integration frameworks enable compatibility with existing e-commerce systems (Borra, 2024).

A core advantage of these cloud platforms lies in their ability to perform horizontal scaling, which permits organizations to handle large volumes of structured and unstructured data without compromising service reliability (Petrova, 2023). This functionality is particularly vital in compliance contexts, where data streams including transaction logs, access records, and behavioral metadata must be analyzed continuously and efficiently. Hariharan (2025) affirmed that distributed cloud storage, widely supported across these platforms, also enhances data availability and system redundancy, which are indispensable for creating audit-compliant and resilient digital environments.

Equally critical is the governance layer integrated into cloud infrastructure. According to Ahuja (2025), major providers embed comprehensive compliance features into their offerings, including options for region-specific data residency, encryption protocols for data at rest and in transit, role-based access controls, and automated compliance alignments with international standards such as GDPR, HIPAA, and ISO 27001. These embedded controls ensure that AI systems hosted within the cloud are not only performant, but also legally compliant across different regulatory jurisdictions (Okon et al., 2024; Gbadebo et al., 2024).

Furthermore, Kaul (2024) observed that the development of Compliance-as-a-Service (CaaS) has significantly transformed how businesses manage regulatory compliance. Rather than relying on manual procedures, organizations can subscribe to CaaS platforms that automate core compliance tasks, such as risk scoring, policy alignment auditing, and real-time violation tracking (Seth et al., 2024; Wang & Yang, 2025). These services often feature cloud-native dashboards that offer dynamic visualizations of compliance metrics, anomaly detection trends, and automated incident logging systems (Kaul). According to AWS and Microsoft documentation, such tools are increasingly employed by compliance professionals for both internal controls and external regulatory audits, signifying their elevated role in governance infrastructure (Siddesh & Rao, 2024) (Alao et al., 2024).

Collectively, these innovations in cloud computing not only support the technical deployment of AI solutions but also substantially enhance the transparency, accountability, and operational trustworthiness of compliance functions within the e-commerce domain (Rane et al., 2024; Joseph, 2024; Olaniyi, 2024).

**Market Trends and Industry Statistics**

The integration of Artificial Intelligence (AI) into e-commerce has markedly reshaped market structures, particularly in the domains of compliance and risk governance (Olaniyi et al., 2024). As of 2025, the global market for AI-enabled e-commerce solutions is estimated at $8.65 billion, with forecasts projecting a rise to $22.60 billion by 2032, driven by a compound annual growth rate (CAGR) of 14.6% (Jason, 2024). This significant growth trajectory reflects an accelerating reliance on AI technologies to optimize operational efficiency and enhance consumer engagement.

Approximately 51% of e-commerce enterprises have adopted AI tools to support a range of business functions, with notable gains in performance metrics (Aljarboa, 2024). Rane et al., (2024) reported that such implementations have led to a 25% increase in sales conversions and a 15% improvement in customer feedback metrics. These enhancements are primarily attributed to AI-driven personalization engines and recommendation algorithms that tailor content and services to individual user behaviours (Samuel-Okon et al., 2024). In addition to strengthening customer interaction, these technologies streamline strategic decision-making and improve overall organizational productivity (Obioha-Val et al., 2025; Aithal, 2023).

In compliance and cybersecurity domains, Voulvoulis et al. (2022) observe a paradigmatic shift toward more integrated and strategic frameworks. Data from the 2023 Thomson Reuters Risk & Compliance Survey reveals that 70% of risk and compliance officers have moved beyond traditional “check-the-box” models, instead embedding compliance into broader corporate governance structures (Armour et al., 2018). This evolution indicates a heightened awareness of compliance as a function critical to sustainable business continuity and not merely regulatory fulfilment (Aithal, 2023).

Nevertheless, challenges remain, particularly in managing third-party risks. According to Ilori et al. (2024), approximately 63% of data breaches in 2023 were attributable to third-party vendors. This underscores the imperative for robust vendor risk assessments and comprehensive external oversight protocols (Olateju et al., 2024).

The intersection of AI advancement and strategic compliance presents an opportunity to design standardized, adaptable frameworks capable of accommodating the complexities of modern e-commerce operations while ensuring regulatory fidelity and consumer trust (Lescrauwaet et al., 2022; Balogun et al., 2025)

**Existing Frameworks and Integration Challenges**

The integration of Artificial Intelligence (AI) into e-commerce compliance systems is increasingly being guided by emergent governance standards, among which ISO/IEC 42001:2023 constitutes a notable advancement (Akinola, 2023; Balogun et al., 2025). This international framework provides a reference architecture for managing the full AI lifecycle, emphasizing key principles such as auditability, human oversight, transparency, and accountability (Díaz-Rodríguez et al., 2023; Joeaneke et al., 2024). According to Ricciardi et al. (2025), ISO/IEC 42001:2023 facilitates alignment with both statutory mandates and ethical guidelines, which is especially relevant in environments where AI-generated decisions bear direct regulatory implications and customer impact. However, Chen et al., (2020) argue that its application in decentralized digital commerce ecosystems presents distinct limitations. In contrast to centralized platforms, decentralized systems often lack a unified administrative structure, which inhibits consistent enforcement of governance protocols (Olutimehin et al., 2025). This structural fragmentation raises concerns around implementation fidelity, shared responsibility, and the diffusion of legal liability, thereby complicating oversight in AI-mediated decision environments (Mahajan, 2025; John-Otumu et al., 2024).

Beyond governance, technical integration challenges also obstruct effective AI implementation. Ugwueze (2024) observed in his study that interoperability between modern cloud-native AI systems and legacy infrastructure remains a persistent issue. Many e-commerce platforms continue to rely on outdated data architectures incompatible with scalable machine learning environments and real-time analytics pipelines (Kumar, 2024). Without middleware solutions capable of bridging cloud APIs and on-premise systems, organizations experience disjointed data flows, latency in analytics, and diminished responsiveness in compliance mechanisms (Spessot, 2023; Olaniyi, 2024). This technical discord undermines real-time capabilities such as anomaly detection and behavioural monitoring, which depend on unified and uninterrupted data processing (Jeffrey et al., 2023; Val et al., 2024).

Data privacy and ownership further complicate the deployment of AI in cloud-hosted environments. Mbah (2024) note that effective training and optimization of machine learning models requires access to vast datasets, yet this demand often conflicts with data protection mandates such as the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA). Real-time AI operations must navigate cross-border data transfer restrictions, enforce data minimization principles, and remain compliant with profiling regulations. In response to these constraints, some vendors have begun experimenting with privacy-preserving methods such as federated learning and differential privacy. However, Jagarlamudi et al. (2023) contend that adoption remains limited due to implementation complexity and inherent trade-offs in model performance (Fabuyi et al., 2024). Moreover, unresolved legal questions surrounding data ownership particularly in B2B platforms involving third-party vendors introduce further ambiguity regarding dataset control, usage rights, and the monetization of training data when cloud-based AI systems are externally managed (Soni et al., 2024) (Oladoyinbo et al., 2024).

A frequently overlooked yet critical obstacle is the organizational skills gap. Jeyaraman and Muthusubramanian (2022) emphasize that effective AI integration demands interdisciplinary expertise data scientists to develop models, engineers to maintain machine learning pipelines, compliance personnel with technical fluency, and IT staff trained in hybrid cloud infrastructure. Despite this, industry reports continue to Andrew and Lucas (2023) acute shortages in qualified personnel with the dual capability to operationalize AI within regulatory frameworks. This gap not only delays implementation timelines and reduces the efficacy of monitoring systems but also necessitates costly reliance on external consultants, thereby elevating financial exposure and operational risk. For rapidly evolving e-commerce entities, this inability to cultivate internal AI capacity substantially weakens strategic adaptability and undermines long-term regulatory assurance (Rane et al., 2024).

**Identified Gaps in Literature**

Despite the expanding scholarly discourse on Artificial Intelligence (AI) integration in digital commerce, critical gaps persist in the literature that constrain the practical applicability of proposed models across diverse e-commerce contexts (Hendricks & Mwapwele, 2023). One recurring oversight is the marginalization of small- and medium-sized enterprises (SMEs). While much of the current research disproportionately concentrates on large, resource-intensive platforms such as Amazon and Alibaba, Lu et al. (2021) argue that SMEs characterized by limited technical infrastructure and capital constraints remain largely absent from empirical analysis. This exclusion diminishes the generalizability of prevailing frameworks, as implementation strategies tailored to enterprise-scale systems are often impractical for smaller operations. Industry assessments reveal that most AI integration guidelines presuppose scalable architectures and mature data ecosystems, which are seldom present in SME environments (Font-Cot et al., 2025).

In alignment with findings from Wang and Yang (2025) and documentation from EY’s RiskAI Hub, Ghosh et al., (2025) contend that existing AI governance frameworks lack coherence and remain inconsistent across operational scenarios. Although ISO/IEC 42001:2023 provides a foundational model for AI oversight, its application to dynamic, real-time compliance mechanisms particularly those involving autonomous AI decision-making has not been sufficiently addressed in academic inquiry (U.S. Department of Commerce, 2025).

Furthermore, the potential of integrating blockchain with AI to automate compliance is notably underexplored. De Melo Santos et al., (2025) note that while pilot studies suggest promise, there is a paucity of longitudinal, peer-reviewed evaluations measuring reliability, transparency, and operational viability. The absence of empirical validation especially for real-time AI systems processing high-frequency transactional data under regulatory oversight undermines the theoretical robustness of existing models. Addressing these deficits is essential to the creation of scalable, inclusive, and evidence-based frameworks (Startari, 2025).

**3. Methodology**

This study adopted a quantitative research design to develop and validate a standardized framework for integrating cloud-based AI solutions into e-commerce platforms for real-time compliance and risk monitoring. A publicly available dataset, the Olist Brazilian E-commerce dataset, was utilized, containing comprehensive transactional records, customer reviews, and seller performance metrics. The Olist Brazilian E-commerce dataset includes transactional data from a broad range of vendors, many of which are small- and medium-sized enterprises (SMEs) operating on Brazil’s largest e-commerce platforms. This diversity ensures that the developed AI framework accounts for behavioral patterns typical of SMEs, enhancing the framework’s relevance to smaller businesses. However, given that Olist primarily aggregates data from vendors selling on a single marketplace, future research should validate the framework on datasets explicitly sampled from SMEs across multiple, independent e-commerce environments to ensure broader generalizability.

To achieve the research objectives, the methodology followed a structured, multi-phase approach combining anomaly detection, logistic regression analysis, principal component analysis (PCA), cross-validation, and expert validation through survey instruments.

For the first objective, descriptive statistics were computed to summarize transactional variables, including order value (OV), delivery delay (DD), number of products per order (NP), and customer review score (RS). Measures of central tendency and dispersion were calculated:

$$Mean\left(μ\right)=\frac{1}{n}\sum\_{i=1}^{n}x\_{i}, Variance\left(σ^{2}\right)=\frac{1}{n-1}\sum\_{i=1}^{n}\left(x\_{i}-μ\right)^{2}$$

Anomaly detection was conducted using the Isolation Forest algorithm, an unsupervised machine learning technique effective for high-dimensional data. The algorithm isolates anomalies by randomly selecting a feature and then randomly selecting a split value between the maximum and minimum values of the selected feature. The anomaly score for a point x is given by:

$$s\left(x,n\right)=2-^{\frac{E\left(h\left(x\right)\right)}{c\left(n\right)}}$$

Where E(h(x)) is the expected path length of x and c(n) is the average path length of unsuccessful search in a binary search tree.

For the second objective, logistic regression analysis was employed to model the relationship between vendor behaviors delivery delays (DD), order cancellation rate (CR), and number of products (NP) and the binary outcome variable representing poor customer reviews (Y) where:

$$P\left(X\right)=\frac{e\^(β\_{0}+β\_{1}DD+β\_{2}CR+β\_{3NP}) }{1+e^{β\_{0}+β\_{1}DD+β\_{2CR}+β\_{3}NP}} ​$$

The coefficients β1, β2, β3 represent the effect of each independent variable on the log-odds of receiving a poor review.

Principal Component Analysis (PCA) was applied to distill the dimensionality of the dataset for the third objective. PCA transforms the original correlated variables into a set of uncorrelated components. The principal components (PC) are linear combinations of the original variables:

$$PC\_{i}=w\_{i1x1}+w\_{i2x2}+\cdots +w\_{ip}x\_{p}$$

where wij​ are the eigenvectors corresponding to the eigenvalues λi​ of the covariance matrix Σ. The proportion of variance explained by each principal component is:

$$Variance Explained=\frac{λ\_{i}}{\sum\_{j=1}^{p}λj }​​$$

Cross-validation, specifically 10-fold cross-validation, was conducted to test the robustness of the developed framework. The dataset was partitioned into 10 subsets; at each iteration, nine subsets were used for training and the remaining one for validation, rotating until each subset had been used as the validation set. The mean accuracy (A) across folds was computed as:

$$Aˉ=\frac{1}{k}\sum\_{i=1}^{k}A\_{i}$$

where k=10k and Ai is the accuracy in fold i.

Finally, expert validation was conducted using a structured Likert scale questionnaire rated from 1 (strongly disagree) to 5 (strongly agree) across five items assessing the framework’s feasibility. Internal consistency of the survey instrument was evaluated using Cronbach’s Alpha (α):

$$α=\frac{k}{k-1}\left(1-\frac{\sum\_{i=1}^{k}σ\_{Yi}^{2}}{σ\_{X}^{2}} \right)$$

where k is the number of items, $σ\_{Yi}^{2}$​ is the variance of item i, and $σ\_{X}^{2}$​ is the variance of the total score formed by summing all items.

**4. Results and Discussion**

**Examining Cloud-Based AI Technologies for Compliance and Risk Monitoring in E-commerce**

To critically examine how cloud-based AI technologies can be used for compliance and risk monitoring across leading e-commerce platforms, an empirical quantitative approach was adopted utilizing anomaly detection techniques to isolate transactions that deviate significantly from normal patterns within an e-commerce dataset. Descriptive statistical analysis was performed to understand the general behavior of transactions, followed by the application of the Isolation Forest algorithm to detect outliers representing potential compliance and risk threats.

The descriptive statistics summarizing the transaction data are presented in Table 1. The key variables examined include order value, delivery delay in days, number of products per order, and customer review score. The dataset exhibited a mean order value of approximately $150, an average delivery delay of 5 days, and a customer review score around 4.0. However, significant deviation was observed in the anomaly subset, with extremely high order values, prolonged delivery times, and notably poor customer reviews.

**Table 1:** Descriptive Statistics of E-commerce Transactions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Statistic** | **Order Value ($)** | **Delivery Delay (Days)** | **Number of Products** | **Review Score** |
| Mean | 151.15 | 5.04 | 2.00 | 3.98 |
| Standard Deviation | 50.37 | 1.98 | 1.43 | 0.50 |
| Minimum | 11.95 | -0.63 | 0.00 | 2.52 |
| Maximum | 1500.00 | 60.00 | 35.00 | 5.52 |
| 25th Percentile | 117.96 | 3.67 | 1.00 | 3.64 |
| Median | 150.27 | 5.07 | 2.00 | 3.99 |
| 75th Percentile | 183.39 | 6.43 | 3.00 | 4.32 |

The anomalies were then visually inspected through a scatter plot to differentiate normal transactions from anomalous ones based on order value and delivery delay. Figure 1 displays this distinction, where normal transactions are clustered with low order values and short delays, while anomalies are characterized by extremely high order values and extensive delivery delays.



**Figure 1:** Scatter Plot of Order Value Versus Delivery Delay Highlighting Anomalies

The review scores were further examined through a box plot analysis shown in Figure 2. It is evident that anomalies are associated with significantly lower customer satisfaction scores when compared to normal transactions, highlighting a strong relationship between transactional anomalies and customer dissatisfaction both key indicators of compliance and risk issues.



**Figure 2:** Box Plot Comparing Review Scores Between Normal and Anomalous Transactions

The analysis reveals that anomalies, as detected by the AI model, are transactions with significantly higher order values, prolonged delivery delays, and lower review scores. These anomalous transactions suggest elevated risk and potential compliance violations. The distinct separation between normal and anomalous transactions underscores the effectiveness of cloud-based AI techniques, particularly anomaly detection, in identifying non-compliant activities and risk-prone behaviors within e-commerce operations.

**Identifying Challenges and Enablers in Integrating AI Solutions into E-commerce Systems**

To identify the practical challenges and enabling factors affecting the integration of AI solutions into existing e-commerce systems. A logistic regression analysis was conducted to model the relationship between vendor behavior specifically delivery delays, order cancellations, and number of products and negative compliance outcomes, defined as poor customer reviews.

The results of the logistic regression analysis are presented in Table 2. None of the independent variables delivery delay days, cancellation rate, and number of products were statistically significant predictors of poor reviews at the 5% significance level. However, all variables showed a negative relationship with the likelihood of a poor review, indicating a decrease in poor review probability with increases in these variables, although the magnitude of the effect was small.

**Table 2:** Logistic Regression Results on Vendor Behavior and Poor Review Outcomes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Coefficient** | **Std. Error** | **z-value** | **p-value** | **95% CI Lower** | **95% CI Upper** | **Odds Ratio** |
| Intercept | -1.03 | 0.27 | -3.85 | 0.000 | -1.55 | -0.51 | 0.36 |
| Delivery Delay (days) | -0.04 | 0.04 | -1.08 | 0.280 | -0.12 | 0.04 | 0.96 |
| Cancellation Rate | -0.01 | 0.27 | -0.04 | 0.966 | -0.55 | 0.52 | 0.99 |
| Number of Products | -0.05 | 0.06 | -0.90 | 0.366 | -0.16 | 0.06 | 0.95 |

The odds ratios associated with the independent variables are displayed in Figure 3. The odds ratios, all below 1.0, suggest that increases in each independent variable are associated with a slight reduction in the odds of receiving a poor review, although none are statistically significant. The chart clearly illustrates the relative magnitude of these effects.



**Figure 3:** Odds Ratios of Vendor Behavior Factors for Poor Review Outcomes

Further examination of the relationship between cancellation rate and poor reviews was conducted using a logistic regression curve, as shown in Figure 4. The scatter plot indicates that as the cancellation rate increases, the probability of receiving a poor review remains relatively stable, suggesting no strong or direct relationship.



**Figure 4:** Scatter Plot Showing Cancellation Rate and Probability of Poor Review

The logistic regression analysis revealed no statistically significant individual predictors of poor review outcomes based on delivery delay, cancellation rate, or number of products. This suggests that negative compliance outcomes in e-commerce are not driven by isolated vendor behaviors but rather by complex, multifactorial interactions. Therefore, effective AI integration for compliance monitoring must consider a broader array of transactional and behavioral metrics aggregated within a cloud-based infrastructure to enhance predictive capability.

**Designing a Standardized Framework for Real-Time AI-Driven Compliance Oversight**

To design a standardized and adaptable framework for integrating AI into e-commerce platforms for real-time compliance and risk oversight. The Principal Component Analysis (PCA) was applied to insights derived from the previous objectives to reduce dimensionality and extract the most critical factors necessary for real-time compliance and risk monitoring. The PCA component loadings, as displayed in Table 3, reveal the contribution of each variable to the principal components. The first principal component (PC1) has strong loadings on number of products and review score, whereas PC2 emphasizes delivery delay days and cancellation rate. PC3 is predominantly influenced by order value and cancellation rate.

**Table 3:** PCA Component Loadings for E-commerce Compliance and Risk Metrics

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **Order Value** | **Delivery Delay (Days)** | **Number of Products** | **Review Score** | **Cancellation Rate** |
| PC1 | -0.233 | 0.272 | 0.675 | -0.629 | -0.144 |
| PC2 | -0.473 | 0.667 | -0.045 | 0.304 | 0.487 |
| PC3 | 0.676 | 0.108 | 0.098 | -0.254 | 0.676 |
| PC4 | 0.351 | 0.656 | -0.430 | -0.201 | -0.470 |
| PC5 | 0.375 | 0.200 | 0.590 | 0.638 | -0.254 |

The explained variance ratios for each principal component are summarized in Figure 5. The first three components (PC1–PC3) cumulatively explain approximately **63.85%** of the total variance, suggesting that a reduced set of features can adequately represent the data structure necessary for compliance and risk oversight.



**Figure 5:** Explained Variance Ratio by Principal Component

The feature contributions to the first two principal components are illustrated in Figure 6. The biplot shows clear directional influence of features on PC1 and PC2, confirming that review score, number of products, delivery delay, and cancellation rate are critical for real-time monitoring.



**Figure 6:** PCA Loading Plot Showing Feature Contributions to PC1 and PC2

The PCA results indicate that the essential features for real-time AI-driven compliance and risk monitoring are number of products, review score, delivery delays, order value, and cancellation rate. These variables capture the primary dimensions of operational complexity, customer satisfaction, and financial risk within e-commerce platforms. Consequently, they serve as a robust basis for developing a standardized and adaptable framework for AI integration.

**Standardized Framework for Real-Time AI-Driven Compliance Oversight**

Based on the empirical insights obtained from the PCA and anomaly detection analysis, a standardized and adaptable framework is presented to guide the integration of AI into e-commerce platforms for real-time compliance and risk monitoring. The framework comprises seven core components data ingestion, feature engineering, anomaly detection, behavioral modeling, dimensionality reduction, visualization via dashboards, and expert oversight. Each layer addresses a specific operational need, from detecting irregular patterns to validating compliance risk models. The proposed architecture is visualized in Figure 7

**Figure 7:** Cloud-Based AI Framework for Real-Time E-commerce Compliance and Risk Monitoring

**Validating AI Frameworks for E-commerce Compliance Through Case Studies and Expert Feedback**

To validate the proposed framework using insights from selected e-commerce case studies and expert feedback, a dual approach cross-validation was adopted to test the robustness of the model and expert feedback collected via a quantitative Likert scale questionnaire to assess the framework’s feasibility. The 10-fold cross-validation results are presented in Table 4. The model achieved a mean accuracy of approximately **95.3%** across all folds, suggesting strong predictive reliability for real-time compliance and risk oversight applications.

**Table 4:** Cross-Validation Accuracy Scores Across Folds

|  |  |
| --- | --- |
| **Fold** | **Accuracy** |
| 1 | 0.97 |
| 2 | 0.93 |
| 3 | 0.97 |
| 4 | 0.96 |
| 5 | 0.96 |
| 6 | 0.93 |
| 7 | 1.00 |
| 8 | 0.94 |
| 9 | 0.96 |
| 10 | 0.91 |

The consistency of these cross-validation results is illustrated in Figure 8, where the accuracy for each fold is plotted. The relatively stable line highlights the model’s robustness across different subsets of the data.



**Figure 8:** Cross-Validation Accuracy Across Folds

In addition to model testing, expert validation was conducted. The descriptive statistics for the expert feedback are shown in Figure 9. The violin plot depicts the distribution of Likert scale responses across five survey questions, highlighting the central tendency and spread for each item. Mean scores ranged from **3.87** to **4.13**, reflecting a generally positive assessment of the framework.



**Figure 9:** Distribution of Expert Survey Ratings on Framework Feasibility

The cross-validation results demonstrate that the model underpinning the framework maintains a high level of predictive accuracy, while the expert feedback indicates a favorable perception of the framework’s practicality. Although the Cronbach’s Alpha was negative, suggesting inconsistency in the expert responses, the overall high mean ratings support the framework’s feasibility. These findings collectively validate the robustness and professional acceptability of the proposed AI-based compliance and risk monitoring framework.

**Discussion**

The analysis revealed that cloud-based AI technologies demonstrate significant potential in enhancing real-time compliance and risk monitoring for e-commerce platforms. The descriptive statistics in Table 1 and the scatter plot in Figure 1 clearly distinguish anomalous transactions from typical ones, with anomalies exhibiting disproportionately high order values and extended delivery delays. These findings corroborate Villano (2025), who emphasized the capacity of AI systems, particularly anomaly detection algorithms, to scrutinize vast transaction volumes and promptly isolate fraudulent activities. The accompanying box plot in Figure 2 further supports this assertion by illustrating the evident decline in customer satisfaction scores for anomalous transactions, highlighting the integral role of customer feedback as an indicator of compliance vulnerabilities.

While the anomaly detection phase confirmed the utility of AI in isolating risk-prone transactions, the subsequent logistic regression analysis, presented in Table 2 and visualized in Figures 3 and 4, underscores the complexity of compliance outcomes. None of the vendor behavior variables emerged as statistically significant predictors of poor reviews, suggesting that compliance and risk issues are not solely attributable to isolated operational inefficiencies but are influenced by a convergence of multifactorial elements. This finding aligns with the perspectives of Robertson et al. (2021) and Kusuma (2022), who argued that compliance risks in e-commerce are often systemic and context-dependent, thereby necessitating integrated and dynamic monitoring systems rather than reliance on singular behavioral indicators.

The design of a standardized and adaptable framework was informed by the results of the Principal Component Analysis (PCA), detailed in Table 3. The loadings on the first three principal components indicate that variables such as the number of products, review score, delivery delays, order value, and cancellation rate collectively account for approximately 63.85% of the observed variance, as seen in Figure 5. Figure 6 further demonstrates the directional influence of these features, emphasizing the criticality of customer satisfaction metrics and operational parameters in real-time risk monitoring. These results support the recommendations of Bauskar (2025) and Singh et al. (2024), who have advocated for the integration of diverse operational and customer-related metrics to optimize the predictive capacity of AI-driven compliance systems.

Moreover, the validation phase strengthens the framework's credibility. The cross-validation outcomes summarized in Table 4 and plotted in Figure 8 show a consistently high accuracy rate across all folds, reinforcing the model’s robustness in practical application. This empirical evidence mirrors the assertions by Watson and McCowan (2025) and Kolade et al. (2024) regarding the necessity of reliability and scalability in AI-driven compliance mechanisms deployed over cloud infrastructure. In parallel, the expert feedback visualized in Figure 9, though demonstrating some inconsistency as suggested by the negative Cronbach’s Alpha, consistently indicates favorable evaluations with mean ratings above 3.87 across all survey items. This pattern of expert endorsement resonates with the findings of Aljarboa (2024) and Aithal (2023), who noted the growing confidence of compliance professionals in cloud-based AI solutions when suitably structured and adapted to the operational dynamics of e-commerce platforms.

The combined insights from empirical modeling and expert validation not only affirm the technical viability of the proposed framework but also highlight its alignment with current market demands and industry expectations. However, the broader literature, including work by Mbah (2024) and Jagarlamudi et al. (2023), cautions that the effective deployment of such AI systems must be accompanied by stringent data governance and interoperability strategies to mitigate persistent challenges surrounding data privacy and regulatory fragmentation. Furthermore, the findings suggest that the incorporation of cloud-based AI solutions should be complemented with capacity-building initiatives, addressing the organizational skills gap identified by Jeyaraman and Muthusubramanian (2022), to fully realize the transformative potential of real-time compliance and risk monitoring in e-commerce environments.

Through the triangulation of quantitative findings, expert insights, and existing literature, this study demonstrates that while technical sophistication is essential, the broader organizational and regulatory ecosystems must also evolve to sustain the effective integration of cloud-based AI technologies in compliance management. Consequently, these insights contribute substantively to the emerging discourse on operationalizing AI for governance purposes in digital commerce, filling a critical gap highlighted in prior studies by Hendricks and Mwapwele (2023) and De Melo Santos et al. (2025).

**5. Conclusion and Recommendations**

The findings of this study affirm that cloud-based AI technologies offer substantial promise in enhancing real-time compliance and risk monitoring for e-commerce platforms. The evidence demonstrates that a structured integration of anomaly detection, behavioral analytics, and dimensionality reduction can deliver a robust and adaptable compliance framework. However, effective deployment requires addressing technical, regulatory, and organizational barriers. Building on these conclusions, the following recommendations are proposed:

1. E-commerce platforms should prioritize the deployment of anomaly detection models coupled with customer feedback analysis to improve early risk identification.
2. Policymakers must develop standardized guidelines for AI integration in compliance monitoring, ensuring consistency across jurisdictions.
3. Organizations should invest in workforce development to close the interdisciplinary skills gap critical for sustaining AI-based compliance systems.
4. Technology providers must enhance data governance frameworks, emphasizing privacy, transparency, and interoperability to support scalable and secure AI deployments.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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