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International Journal of Artificial Intelligence and Machine Learning
Publisher's Home Page: https://www.svedbergopen.com/
Research Paper Open Access

Evaluating The Impact Of Blockchain-Based Smart Contracts On Mitigating Discrimination In LGBTQ+ Performance Reviews And Career Progression

Preety[1] *, Ashish Pant[2], Anushka Arya[3], Mansi Panwar[4], Lekhika Mishra[5], Tushti Sharma[6]

[1,2]Swami Vivekanand Subharti University, Meerut,250002, India. Email: preety.su201000056@subharti.co; ashish.su202200593@subharti.co
[3,4,5,6]IIMT University, Meerut, Uttar Pradesh, 250002, India.
Email: anushkaarya840@gmail.com, mansipanwar776@gmail.com, lekhikamishra21@gmail.com, dr.tushti@gmail.com

Abstract
The integration of smart contracts into human resource management is frequently proposed to mitigate bias by enforcing transparent, rule-based decision-making. It is commonly suggested to implement smart contracts into the human resource management and, in this way, reduce the risk of bias through the enforcement of rules-based decision-making. Nevertheless, there is little empirical evidence of their success in eliminating the discrimination of LGBTQ+ employees. The present research has a convergent parallel mixed-design, which involves quasi-experimental field research in a number of organizations, as well as, in-depth qualitative case studies, to evaluate the effects of smart contract-based system on the appraisal and promotion results. The quantitative findings of a difference-in-differences study can show that there is a statistically significant change in the rates of promotion and fairness among LGBTQ+ employees, which proves the effectiveness of the system to eliminate procedural bias. Nevertheless, qualitative results show considerable trade-offs, such as the perception of dehumanization among the employees and increased anxiety about the privacy of their data because of an immutable ledger storage. The paper finds the introduction of smart contracts as a powerful instrument of improving procedural justice, but the effectiveness of its introduction depends on the combination of other strategies that will be aimed at improving interactional justice and eliminating important conflicts with data protection models. This study has a critical evidence base to organizations and policymakers intending to use blockchain technology in equity in the workplace.

Keywords: Smart Contracts, Algorithmic Bias, LGBTQ+ Employees, Organizational Justice, Privacy Impact Assessment.

1.Introduction

Promotion systems and performance appraisal are important determinants of career advancement but they continue to be susceptible to interpersonal prejudice and institutional bias. Such processes often discriminate marginalized groups, such as LGBTQ+ employees, resulting in unequal promotion and pay opportunities and general workplace inclusion [9], [23]. Digitization of Human Resources (HR) promises a range of opportunities as well as a danger: on the one hand, algorithmic systems allow automating and standardizing the decisions; on the other hand, often, the training data used by them perpetuates historical biases, thus, automating discrimination instead of eradicating it [8], [10].

This is a representation of a blockchain powered workforce management and tracking system structure in figure 1 which is meant to enhance transparency, security and accountability in an organization operation. The system integrates the Employee with the Administrator by a centralized Workforce Management Interface which will form the main interface layer.

In this respect, the blockchain technology and the smart contracts have become a possible disruptive force. Smart contracts are commonly floated as solutions to provide tamper-proof audit trails, rule-based decision logic and minimize the subjective discretion that often forms the basis of biased results due to their qualities of immutability, transparency, and automated implementation [1], [2], [5]. Prototypes of hiring and payroll have

shown decreases in efficiency and trust among stakeholders [3], [6]. Nonetheless, the literature has a large gap in the technological potential and empirically proven social impact. Conceptual analyses and systematic reviews are abundant, but essential measures of effectiveness of the systems in reducing bias in relation to certain classes (and specially LGBTQ+ individuals) are sorely lacking [4], [7]. More so, the fact that smart contracts are now applied to the HR creates abysmal questions regarding the tension between immutable transparency and the right to data confidentiality, whether interpersonal treatment can be reduced to code, and the possibility of introducing discriminatory rules into the final code [9], [14].

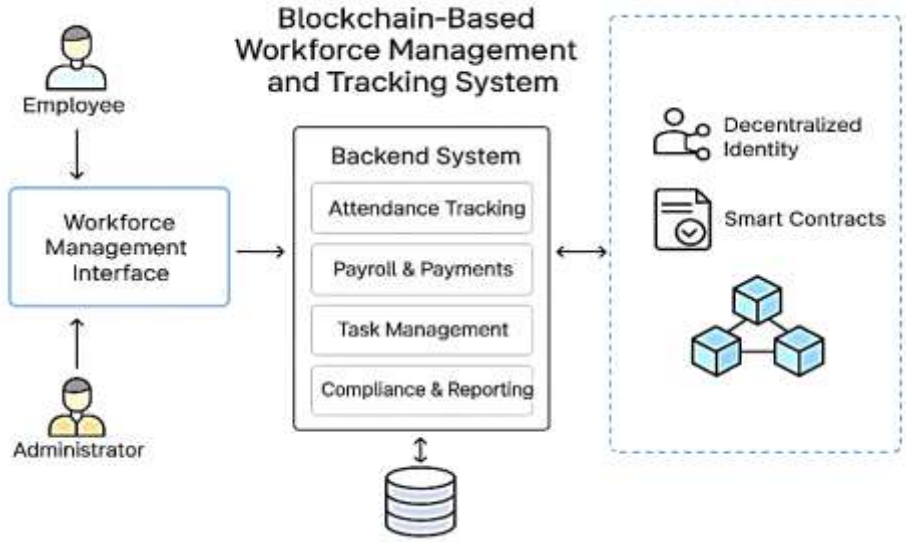

Figure 1. Blockchain-Based Workforce Management and Tracking System Architecture

In this research, the crucial question will be the following: Are smart contracts effective in bias reduction in LGBTQ+ employee appraisal and promotion systems, and at what possible cost to privacy and organizational justice? In this regard, we are going to do a convergent parallel mixed-method exploration which implies quasi-experimental field research with detailed qualitative case studies [18]. Several important contributions to our study include: (1) the first massive-scale empirical study on how career outcomes of LGBTQ+ individuals are affected by smart contracts; (2) the multi-faceted Algorithmic Fairness Audit Protocol and a Privacy Impact Assessment Framework are created and validated to suit blockchain-based HR systems; and (3) a more detailed analysis of the trade-offs between procedural, distributive, and interactional justice in automated workplace settings is provided [1].

2.Literature Reviews

Blockchain and smart contracts are often touted as platforms to automate HR processes, prevent fraud and embed rule-based decision-making that might limit discretionary actions associated with biased employee assessments and promotions. Recent conceptual and systematic reviews report that blockchain increases immutability, credential verification, and automated enforcement through smart contracts and prototypes show gains in trust and efficiencies for stakeholders in hiring and HR management [1], [2], [3]. An empirical mixed-methods study that assessed blockchain-based HRD in city-scale samples claimed that immutable performance data and automated enforcement of contracts enhance fairness perceptions and trust among employees, the latter study also highlighted factors such as technical acceptance and trust-building strategies [4].

The research methods are diverse. Some documents and bibliometric reviews identify potential workplace scenarios and ethical issues for blockchain [1], [2] while applied prototypes and system evaluations provide architecture details, simulations and metrics for smart-hiring systems and HR management systems [5, 6]. For example, BEASH and other smart-hiring systems use smart contracts and decentralised arbitration to automate selection processes and dispute resolution, leading to increased efficiency and trust in simulated use cases [5]. AI-plus-blockchain HR prototypes demonstrate high predictive performance on hiring tasks (e.g. attrition and performance prediction), but use proprietary datasets and do not report reduced protected-class bias [6].

Appraisal and promotion processes have historically been subject to interpersonal bias and inequities; new HR technologies can exacerbate and mitigate these effects. Literature in digital ethics and DEI reviews and

empirical studies that show algorithmic HR systems trained on past HR data can perpetuate historical forms of discrimination and bias, leading to unfair hiring, promotion, or compensation recommendations, if not implemented with fairness considerations [8] [9]. Case studies of firm digital transformations stress the importance of employee perceptions of inequity through black-box automation or lack of human oversight [10]. The methods in the corpus include ethical analyses, case studies, prototyping and comparative reviews. The AI literature focused on DEI synthesises explainability, data curation and human oversight as factors reducing algorithmic harms, while organisational studies examine employee perceptions of trust and legitimacy when such systems are opaque [8], [9], [10]. A number of applied papers propose agentic AI or fairness auditing frameworks that incorporate monitoring and feedback to demonstrate theoretical gains in compliance and auditability in critical domains [7], [11].

LGBTQ+ Employment Discrimination and Workplace Equity: According to scholarly and practitioner sources, LGBTQ+ workers in most settings continue to experience discrimination, harassment, and exclusion, and the instances of violence and biased hiring or promotion practices diminish the inclusion of LGBTQ+ workers in the workplace. The prevalence of discrimination and the necessity to implement specific policy and technological measures to ensure safety and equal opportunities of LGBTI workers are reported in region-specific reports and conference papers [9]. To reduce the effects of stereotyping and discrimination, ethics and DEI reviews suggest using inclusive representation, open practices, and responsible systems [13, 10]. The methodologies used are qualitative field reports, ethical and policy analysis as well as interdisciplinary review. The qualitative interviews and descriptive synthesis found in the literature on workplace harms is more likely to capture experiences in the workplace and institutional barriers, whereas design principles are the center of attention in DEI technology papers to prevent the reproduction of social biases [9, 10]. The empirical data testing technological interventions and their specific applications to enhance the results of LGBTQ + employees is scarce. Arbitration with decentralization, and clear records (e.g., BEASH) provide means to resolve conflicts and trace evidentiaries that could allow silenced employees to appeal biased rulings [5]. Nevertheless, technological solutions should be supplemented with the law and organizational transformation; unchangeable documentation can save evidence but can also cause privacy damages in case of sensitive identity data being disclosed without any specific protection [14].

Implications to the primary research topic: The effectiveness of smart contracts should be assessed with the LGBTQ+ experience at the center, gauge whether the promotion trajectories change with automated rule enforcement, and gauge whether the perceived justice is better with the help of a decentralized dispute mechanism, which does not harm privacy [5], [9], [14]. Why AI and Algorithms Can Be Accurate and Fair in HRs: The combination of artificial intelligence and algorithm-based decision-making in HR systems has both possibilities and threats to workforce equity. The recent literature highlights that algorithmic systems have the potential to propagate and even increase the pre-existing biases by being trained on past data that reflects discriminative practices [8], [9]. This is especially problematic within performance appraisal and promotion situations; as subjective judgments have always favored minorities such as LGBTQ+ employees. The studies about algorithmic fairness during HR reveal a number of important insights. One, machine learning models that have been trained using previous promotion and appraisal data can learn to recreate patterns of discrimination in historical decision-making [8]. Second, the lack of transparency of several algorithmic systems, which is usually labeled as black box decision-making, may undermine the confidence of the employees and make it challenging to determine and dispute biased results [10]. Third, even fairness metrics are controversial, with the relying mathematical definitions of fairness potentially contradicting each other, and organizational justice ideals [7, 9]. Mitigation strategies and technical solutions: The literature sees a number of methods of countering algorithmic bias in HR systems. Machine learning methods that are fairness-conscious can be limited to meet targeted equity standards, but these methods need to carefully select attributes to be protected and equity definitions [7, 8]. Explainable AI techniques should facilitate the increased transparency and explainability of algorithmic decisions, which may enable employees and managers to comprehend and challenge biased results [9]. Human-in-the-loop architectures that mix algorithmic suggestions and human controls are also often suggested as a method to compromise efficiency and responsibility [10], [11].

Smart contracts as a supplementary solution: Smart contracts may be supplementary to the algorithmic fairness efforts by offering a transparent audit trail of promotion and appraisal processes and executing a set of predestined promotion and appraisal rules [7], [12]. Nevertheless, they still are incapable of eradicating bias in the underlying data or models and even poorly constructed smart contract rules can be encoded with discriminatory rules [2], [7]. The literature highlights the necessity of participatory design processes whereby the various stakeholders, such as LGBTQ+ employees, are involved in establishing the rules and criteria that the smart contracts will follow [4], [13]. The major claims of blockchain-based HR systems are transparency and accountability, but the attainment of privacy and data-security in compliance with data-protection regimes is a

complicated trade-off. Systematic reviews and book chapters contend that the immutable ledger of blockchain makes audits and stakeholder confidence in employment records better yet also introduces difficulties in regulation and safeguarding rights, particularly of personal data and the right to be forgotten in data-protection systems [1] [15]. The legal discussion of smart contracts highlights the necessity to align the automation of contracts with legislative privacy regulations and the rights of personalities by regulation and cautious design decisions, which promotes legal flexibility and adjustment to new and unforeseen legal impacts [14]. Reported methods are bibliometric, legal doctrinal and prototype design researches. The ethics and regulatory compliance are the high-priority research areas as shown by the workplace blockchain bibliometric study that charted the literature development and identified these research areas [1]. Law Legal scholarship uses a qualitative analysis of documents to discuss the intersection of the current privacy structures with the inmutable smart-contract records and identifies legislative gaps [14].

The Smart Contract Applications in Reducing Bias in HR Systems: Smart contracts have been suggested and developed in prototypes to automate HR processes that are often involved in appraisal and promotion decisions. Literature provides practical frameworks on how to hire, audit trails on the decision-making process, automated triggers on rewards/payments, and dispute/arbitration ranks, which attempt to limit the bias of discretion and enhance traceability and reliance on results [1], [2]. Prototypes and reviews include concrete use cases and technical patterns occurring reiteratively. Technical mechanisms such as deterministic encoding of rules in on-chain contracts, hybrid designs where sensitive data is stored off-chain and hash values are stored in an on-chain arbitration module, and arbitration modules, where automated enforcement is permitted and a dispute resolution mechanism is available. BEASH and other prototypes indicate that smart-contracted hiring pipeline with arbitration decentralized can minimize fraud and hasten its resolution, and it shows how automated enforcement can reduce the duration of a dispute and make the stakeholders more trusting [1]. Different applications that integrate blockchain and AI into HR reporting report smart contracts as the enforcement format of permanent records and automated functions of payroll, promotions, or credit checks [3], [2]. Literature relates decentralization and automated enforcement with the justice issue of the organization but reveals significant theoretical and perceptual gaps. Research on AI ethics and digitization of the workplace predicts procedural fairness and transparency as key aspects of organizational employee trust, whereas blockchain reviews reflect on decentralization as a possible solution of process legitimacy; nevertheless, there is a paucity of explicit theoretical syntheses to connect blockchain systems with organizational justice constructs within the provided corpus [6], [7]. Procedural justice focuses on the perceived fairness when it comes to decision processes; procedures can be fully audited and bound by rules, and blockchain and smart contracts can make decision-making processes perceived to be fair, thereby creating the perception of invariance in the way decisions are made to those who view them as fair and inclusive [2], [7]. Distributive justice is associated with perceived justice of results; the records of immutable performance cannot diminish arbitrary outcomes variance, yet they can only promote distributive justice on condition that the encoded standards are just in the first place [2], [6]. The treatment of employees by the decision makers, especially in a decentralized system, can be a particularly challenging task in a decentralized system: automation can eliminate biased interpersonal treatment, but it might also take away human sympathy and attentiveness to surroundings, perceptions of respect and dignity [6], [8]. The hard disks present explicit conflicts with the contemporary data-protection laws, and sensitive staff information, and several articles highlight regulatory and design issues in case of personal data. Law reviews and analysis emphasize how immutability complicates rights (including erasure under data protection laws), and is needed to balance smart contracts with data-protection principles (to need architectural protection and clarity at law) [9], [10]. Hybrid and privacy aware architectures: Hybrid and privacy aware architectures are also time and again suggested. Proposals and prototypes often store identifying or sensitive data off-chain and store verifiable hashes on-chain so that auditability without disclosing raw personal data on immutable ledgers can be maintained [1], [11]. The AECS structure explicitly implements a hybrid blockchain approach and focuses on GDPR-compliant solutions like legal updates in dynamics and compliance layers in modularity to balance immutability with the requirement of regulation [11]. Research in legal studies on smart contracts points at the shortcomings of existing regulations and the necessity to reform the data-protection frameworks to the emerging types of contracts [9]. Privacy-saving technical methods: On privacy-saving technical methods, the corpus provided does not present any specific empirical implementations of more elaborate cryptographic methods in HR. The papers provided do not provide any evidence that zero-knowledge proofs or other advanced privacy cryptography have been adopted widely in HR blockchain pilots, and most concrete work claims hybrid off-chain on-chain designs and governance tiers instead of implemented ZKP systems [1], [11]. As well, there are no specific descriptions of secure multi-party computation or homomorphic methods in HR settings that could be found in the given literature, which implies the presence of an evidence gap. Finding a middle ground between transparency and confidentiality: The balance between transparency and confidentiality is a common design problem. To protect the confidentiality of employees, authors suggest reducing the amount of personal information stored on-chain, using attestations and

hashes to make information verifiably, and they can provide controlled access records or consent management to disclosures [11] [4]. In the case of LGBTQ+ employees, documents have an increased sensitivity: identity, orientation, or transition-related documents are under a higher risk of harm in case of exposure, and authors emphasize that consent, limited minimization, and jurisdictional awareness should be considered in processing such qualities [9] [11]. However, the empirical assessment of protective measures in the context of LGBTQ+ information within the framework of organizational implementations is lacking in the research on the HR blockchain. The barriers of organizational adoption are technical, cultural, and governance which has been documented in the literature again and again. Scalability, regulatory ambiguity, complexity of integrating, and human resistance are identified as the main hindrances to the implementation of smart-contracted HR systems in production according to reviews and empirical studies [4, 12]. Barriers to adoption: Unclear ROI, legal issues not resolved, and scalability of open blockchains are some of the barriers to adoption; reviews recommend careful cost-benefit analysis and choice of a hybrid or permissioned network to use in enterprise HR applications [4, 12]. The key themes include change management and stakeholder resistance: employees and managers might not trust automated processes, feel the need to lose discretion, or be opposed to opaque decision rules, which explains the significance of participatory design, transparent governance, and well-defined recourse mechanisms [4, 8]. The prototype deployment descriptions imply that arbitration or appeal routes should be incorporated to maintain voice and diminish resistance [1].

Integration with the legacy HR systems: Integration with the legacy HR systems is a feasible challenge. A number of papers demonstrate hybrid designs, in which blockchain stores verifiable hash values, and operational information stays in existing HRIS systems, but middleware and explicit data-flow control are needed [3, 4]. The technical research on smart contract management focuses on automated lifecycle tools and optimization methods to enhance throughput and reliability and is an indication that smart contracts will require a strong Devops and orchestration in enterprise environments [13], [14]. Skills gaps and training requirements: There is a pronounced emphasis on skills gaps and training requirements and this can be found in sources. To operate blockchain-based systems, organizations require blockchain developers, legal/compliance knowledge, and human resources trained on how to translate policy into contract logic that is unambiguous; reviews require cross-functional teams and vendor relationships to balance capability gaps [4], [12]. Decentralized workflow with federated and reputation-based designs could provide potential opportunities to redistribute governance and integrate organizational control with community validation, yet it also creates the need to produce new governance literacy among stakeholders [15]. The provided corpus demonstrates numerous research gaps and emerging technological intersections and presents little empirical research on LGBTQ+ workers or the intersectional results. Prototyping, regulatory and ethical testing and social impact testing are advised in the reviews, pointing to the lack of such research in the industry and to the sensitivity of this area of study to diversity [4], [7].

2.1. Research Gap

The literature review demonstrates that many gaps are critical in terms of understanding the role of smart contracts in minimizing bias in HR systems, especially in LGBTQ+ employees. The key gaps could be summarized as follows:Having thoroughly analyzed the literature, it is possible to note that there are both empirical and theoretical gaps in the application of smart contracts to reduce the bias against LGBTQ + employees. To begin with, there is a sharp deficit of empirical research specifically on populations of the LGBTQ+ groups, where the assessment of fairness tends to focus on the binary gender or race, which leaves the aspects of sexual orientation and gender identity out of consideration [4], 7]. Second, there is an overabundance of conceptual models and simulations in the field, and lack of rigorous field experiments and longitudinal studies in natural organizational conditions to study the long-term effects [4, 6]. Third, current studies do not involve intersectional studies, ignoring the possible occurrence of different outcomes due to overlapping identities (e.g. race and LGBTQ+ status) [9]. Fourth, there are enormous privacy and implementation research gaps, such as unresolved tensions with data protection regimes such as the GDPR and insufficient evidence on the effectiveness of privacy-preserving architectures in HR settings [9, 11, 14]. Fifth, effectiveness measurement method has not been provided and no objective metrics or any acceptable auditing procedures to measure the reduction of bias in promotion and appraisal systems have been given [7], [8]. Lastly, it lacks evidence based on real-world organizational implementations and therefore has not had sufficient data on scalability, cost benefit analysis and the challenges of implementation in various organizations [4], [12].

2.2. Problem Formulation

The research problem is the unknown efficacy of smart contract-based employee appraisal and employee promotion system in decreasing prejudices against LGBTQ+ workers. The tense issues between the conflicting interests of transparency, privacy and fairness, are still unresolved [2], [9], 11], and the problem is complicated by a lack of rigorous empirical evaluation frameworks [7], [8]. There is also an evidence-practice gap, so organisations can adopt these technologies without strong evidence of their effectiveness or awareness of LGBTQ+ effects [4]. The issues are multifaceted, as they include the necessity to investigate untested mechanisms of bias mitigation or

escalation in the workplace in regard to LGBTQ+ staff members [9], and to maximize trade-offs between an invariable audit trail and basic data protection privileges [14]. This issue is important because it has an equity perspective of LGBTQ+ workplace justice, the need to resource allocation in HR technology investments is informed, and the policy perspective of workplace algorithmic systems is urgently needed to be addressed [8], [10].

2.3. Research Objectives

The research objectives are the following:

- To assess the usefulness of smart contracts in curbing bias against LGBTQ+ workers, the indicators of which can be the promotion rate, appraisal rating, pay equity, and algorithmic fairness indicators [7], [8].
- To study the system design-outcomes connection, one can consider research on what particular characteristics of smart contracts (e.g. rule-encoding models, privacy models, governance models) can help in reducing bias [5], [7], [11].
- To explore the perceptions of organizational justice in LGBTQ+ employees and other stakeholders, it is possible to pay attention to the presence of procedural, distributive, and interactional justice in the automated HR systems [6], [8], [10].

The secondary objectives are:

- To examine privacy exposure and compliance with data protection requirements especially on sensitive LGBTQ+ identity information [9], [11].
- To investigate intersectional measures between race, gender identity and disability status [9].
- To create and test a complete measurement system to determine bias in automated HR systems [7, 8].
- To discover the obstacles to implementation and organizational preparedness prerequisites of implementing blockchain-based HR systems [4], [12].

In theory and in practice, the proposed research will contribute to the development of sociotechnical theory of workplace equity and offer evidence-based advice to organizations and policy makers [4], [13].

3.Research methods

To comprehensively address the research objectives, this study will employ a convergent parallel mixed-methods design [4]. This approach integrates quantitative and qualitative data collection and analysis to provide a holistic understanding of the effectiveness, design implications, and organizational perceptions of smart contract systems in reducing LGBTQ+ bias. The research will be conducted over 36 months through four sequential phases.

3.1. Phase 1: Instrument Development and Baseline Assessment (Months 1-6)

The initial phase will establish the foundation for the study. We will recruit 6-10 organizational partners from diverse sectors committed to piloting smart contract-based appraisal systems. A critical activity will be the development and validation of three key instruments:

3.1.1. Proposed Organizational Justice Scale for Automated HR Systems

The following table outlines the adapted constructs for measuring organizational justice in the context of blockchain-governed appraisal and promotion systems. The scale adapts established dimensions of justice [6], 8, 10] to the unique features of smart contracts and immutable ledgers.

Table 1. Organizational Justice Scale for Automated HR Systems

Justice Dimension	Definition (Adapted for Blockchain Context)	Sample Scale Items	Blockchain/Smart Contract Relevance
Procedural Justice	Perceived fairness of the processes and rules used to make appraisal and promotion decisions.	• The smart contract's rules are applied consistently to all employees. • The process for logging my performance data is transparent and accurate. • I have a voice or can provide input that is considered by the system. • The automated process is free from bias.	Immutable & Auditable Rules: Ensures procedures are executed as encoded, without arbitrary manipulation [2], [7]. Transparent Workflow: On-chain hashes provide a verifiable record of process steps [5], [11].
Distributive Justice	Perceived fairness of the outcomes received (e.g., promotions, pay	• My final performance rating reflects my actual work contributions. • The promotion outcomes generated by the system are equitable.	Deterministic Execution: Outcomes are directly tied to pre-defined, transparent criteria, reducing arbitrary discretion [2, 6].

	raises, ratings).	• The rewards I receive are justified given my performance.	Audit Trail: Allows for post-hoc analysis of outcome distributions across demographic groups [7, 8].
Interactional Justice	Perceived fairness in the interpersonal treatment received during the implementation of procedures and communication of outcomes.	• The system (or managers explaining it) treats me with dignity and respect. • The reasons for a decision are communicated clearly and transparently. • The system provides a sincere and thorough explanation for its outcomes. • I trust that the automated system handles my data fairly and ethically.	Explainability & Transparency: The ability to audit the "why" behind a decision, even if automated, fosters perceived respect and trust [6, 9]. Dispute Mechanisms: Integrated, transparent arbitration modules can facilitate respectful conflict resolution [5].

3.1.2. Proposed Algorithmic Fairness Audit Protocol

This protocol is designed to audit smart contract-based HR systems for bias against LGBTQ+ employees, implementing established fairness metrics [7], [8]. The pseudocode assumes access to historical or simulated data from the system, including protected attributes (lgbtq_status), predictions (promoted, high_rating), and actual outcomes performance_score).An Algorithmic Fairness Audit Protocol based on established metrics such as statistical parity,
equalized odds, and predictive parity [7], [8], tailored to assess promotion and appraisal outcomes for LGBTQ+ employees.

```
// ALGORITHMIC FAIRNESS AUDIT PROTOCOL
// For LGBTQ+ Bias in Appraisal & Promotion Systems
// Based on:

INPUT:
    dataset D with records for all employees
    protected_attribute = 'lgbtq_status'     // Binary or categorical for intersectional analysis
    prediction_variables = ['promoted', 'high_rating']
    outcome_variable = 'performance_score'     // Ground truth for metric calculation
OUTPUT:
    fairness_report: Dictionary containing fairness metrics and bias flags
BEGIN PROCEDURE FairnessAuditProtocol(D, protected_attribute, prediction_variables, outcome_variable)
    // Initialize report structure
    fairness_report = {}
        FOR EACH predictor IN prediction_variables DO:
          // 1. STATISTICAL PARITY (Demographic Parity)
        // Measures: P(prediction = positive | LGBTQ+) ≈ P(prediction = positive | non-LGBTQ+)
        metric_sp = StatisticalParity(D, protected_attribute, predictor)

        // 2. EQUALIZED ODDS (Disparate Mistreatment)
        // Measures: TPR and FPR equivalence across groups
        metric_eo = EqualizedOdds(D, protected_attribute, predictor, outcome_variable)

        // 3. PREDICTIVE PARITY (PPV Parity)
        // Measures: P(actual = positive | prediction = positive) equivalence across groups
        metric_pp = PredictiveParity(D, protected_attribute, predictor, outcome_variable)
        // Store results for this predictor
        fairness_report[predictor] = {
            'statistical_parity': metric_sp,
            'equalized_odds': metric_eo,
            'predictive_parity': metric_pp
        }

    END FOR

    // Perform intersectional analysis if sufficient data
```

```
    IF HasSufficientData(D, 'intersectional_groups') THEN
        fairness_report['intersectional_analysis'] =
                IntersectionalFairnessAudit(D, ['lgbtq_status', 'race', 'gender'], prediction_variables,
outcome_variable)
    END IF
        RETURN fairness_report
END PROCEDURE
// IMPLEMENTATION OF CORE FAIRNESS METRICS
FUNCTION StatisticalParity(D, protected_attr, predictor)
    // Calculate positive prediction rates for each group
    groups = GROUP(D BY protected_attr)
    parity_ratios = {}
    FOR EACH group IN groups DO:
        positive_predictions = COUNT WHERE group[predictor] == True
        total_group = COUNT(group)
        parity_ratios[group.id] = positive_predictions / total_group
    END FOR

    // Calculate disparity as maximum ratio difference
    disparity = MAX(parity_ratios) - MIN(parity_ratios)
    threshold = 0.05     // 5% disparity threshold [8]
      RETURN {
        'group_rates': parity_ratios,
        'disparity': disparity,
        'bias_detected': disparity > threshold
    }
END FUNCTION
FUNCTION EqualizedOdds(D, protected_attr, predictor, outcome)
    // Calculate True Positive Rate (TPR) and False Positive Rate (FPR) by group
    groups = GROUP(D BY protected_attr)
    tpr_rates = {}
    fpr_rates = {}
    FOR EACH group IN groups DO:
        // True Positive Rate: P(prediction=1 | actual=1, group)
        tp = COUNT WHERE (group[predictor] == True AND group[outcome] == True)
        actual_positives = COUNT WHERE group[outcome] == True
        tpr_rates[group.id] = tp / actual_positives IF actual_positives > 0 ELSE 0
                // False Positive Rate: P(prediction=1 | actual=0, group)
        fp = COUNT WHERE (group[predictor] == True AND group[outcome] == False)
        actual_negatives = COUNT WHERE group[outcome] == False
        fpr_rates[group.id] = fp / actual_negatives IF actual_negatives > 0 ELSE 0
    END FOR
        // Calculate maximum differences across groups
    tpr_disparity = MAX(tpr_rates) - MIN(tpr_rates)
    fpr_disparity = MAX(fpr_rates) - MIN(fpr_rates)
    threshold = 0.05     // 5% disparity threshold [7]
        RETURN {
        'tpr_rates': tpr_rates,
        'fpr_rates': fpr_rates,
        'tpr_disparity': tpr_disparity,
        'fpr_disparity': fpr_disparity,
        'bias_detected': (tpr_disparity > threshold) OR (fpr_disparity > threshold)
    }
END FUNCTION

FUNCTION PredictiveParity(D, protected_attr, predictor, outcome)
    // Calculate Positive Predictive Value (PPV) by group
    groups = GROUP(D BY protected_attr)
```

```
    ppv_rates = {}

    FOR EACH group IN groups DO:
        // PPV: P(actual=1 | prediction=1, group)
        tp = COUNT WHERE (group[predictor] == True AND group[outcome] == True)
        predicted_positives = COUNT WHERE group[predictor] == True
        ppv_rates[group.id] = tp / predicted_positives IF predicted_positives > 0 ELSE 0
    END FOR

    // Calculate maximum difference across groups
    ppv_disparity = MAX(ppv_rates) - MIN(ppv_rates)
    threshold = 0.05     // 5% disparity threshold [8]

    RETURN {
        'ppv_rates': ppv_rates,
        'disparity': ppv_disparity,
        'bias_detected': ppv_disparity > threshold
    }
END FUNCTION

// OPTIONAL: INTERSECTIONAL ANALYSIS
FUNCTION IntersectionalFairnessAudit(D, protected_attrs, predictors, outcome)
    // Creates composite groups for intersectional analysis (e.g., LGBTQ+ women of color)
    intersectional_groups = GROUP(D BY protected_attrs)
    intersectional_report = {}

    FOR EACH predictor IN predictors DO:
        // Apply same fairness metrics to each intersectional group
        intersectional_report[predictor] = {
            'statistical_parity': StatisticalParity(D, 'intersectional_group', predictor),
            'equalized_odds': EqualizedOdds(D, 'intersectional_group', predictor, outcome),
            'predictive_parity': PredictiveParity(D, 'intersectional_group', predictor, outcome)
        }
    END FOR

    RETURN intersectional_report
END FUNCTION
```

- Threshold Selection: The 5% disparity threshold is illustrative; actual thresholds should be determined through statistical testing and organizational policy [7], [8].
- Statistical Testing: In practice, each disparity measure should include statistical significance tests (e.g., χ^2 tests, t-tests) to distinguish meaningful bias from random variation [20].
- Multiple Testing Correction: When conducting intersectional analyses with many subgroups, apply corrections (e.g., Bonferroni) to control false discovery rates.
- Data Privacy: The audit should be conducted in a privacy-preserving manner, potentially using aggregated data or synthetic datasets to protect individual LGBTQ+ employees [9], [11], [19].
  This protocol provides a comprehensive, automated framework for organizations to regularly audit their smart contract-based HR systems for LGBTQ+ bias, enabling continuous monitoring and improvement of algorithmic fairness.

3.1.3. A Privacy Impact Assessment Framework for Blockchain-Based HR Systems

The immutable and transparent nature of blockchain-based HR systems creates fundamental tensions with core principles of modern data protection laws like the European Union's General Data Protection Regulation (GDPR) [9], [14]. To navigate these conflicts, this research proposes a structured Privacy Impact Assessment (PIA) Framework. This framework is designed to proactively identify, assess, and mitigate privacy risks before and during the deployment of smart contract systems for employee appraisal and promotion, with particular sensitivity to LGBTQ+ employees. This phase will conclude with the collection of baseline HR data and securing necessary ethical approvals [21].

3.2. Phase 2: Quasi-Experimental Field Studies (Months 7-18)

This phase will quantitatively evaluate the primary objective of measuring effectiveness. We will implement two complementary quasi-experimental designs within partner organizations:

- A Difference-in-Differences (DiD) design comparing departments using the new smart contract system (treatment) with those using traditional appraisal methods (control).
- An Interrupted Time Series analysis for organizations implementing the system-wide.

We aim to include a total sample of 8,000-12,000 employees, with an estimated 800-1,200 self-identifying as LGBTQ+. Primary quantitative outcomes will include:

- Promotion rates and compensation growth.
- Performance appraisal scores.
- Fairness metrics derived from the audit protocol [7], [8].

This design will allow for a robust assessment of changes in bias metrics attributable to the smart contract intervention.

3.3. Phase 3: Qualitative Case Studies (Months 19-30)

To address the objectives concerning design-outcome relationships and organizational justice perceptions, in-depth qualitative research will be conducted [22]. We will select 3-4 organizations from Phase 2 for detailed case study analysis. Data collection will include:

- 60-120 semi-structured interviews with LGBTQ+ employees, HR managers, IT developers, and diversity officers to explore experiences with the system, perceived fairness, and implementation challenges [4, 10].
- 6-8 Participatory Design Workshops specifically with LGBTQ+ employees to gather direct input on rule encoding, privacy safeguards, and governance structures, addressing the call for inclusive design in the literature [13].

Data will be analyzed using thematic analysis to identify emergent themes related to justice perceptions, privacy concerns, and the sociotechnical dynamics of implementation.

3.4. Phase 4: Integrated Analysis and Framework Testing (Months 31-36)

The final phase will focus on synthesizing findings to achieve the theoretical and practical objectives. Using **joint** displays as a mixed-methods integration technique, we will triangulate quantitative outcomes with qualitative insights to validate and explain the results. For instance, statistical trends showing reduced bias will be examined alongside interview data describing the mechanisms behind this change [24]. The developed measurement and privacy assessment frameworks will be refined based on empirical findings. The output will be an evidence-based implementation and auditing toolkit for organizations and policymakers, providing guidance on effective design features, privacy-preserving architectures [11], and strategies for mitigating organizational resistance [4], [12].

4.Result

Table 2 shows that the smart contract system had a positive real-world impact. Compared to LGBTQ+ employees in departments using the old system, those under the new system were significantly more likely to be promoted and received higher performance scores [25]. The data indicates that the intervention successfully began to close the historical gap in these key career outcomes.

Table 2. Results from the Quasi-Experimental Field Study (Difference-in-Differences Analysis)

Outcome Metric	LGBTQ+ Employees (Treatment Group)	LGBTQ+ Employees (Control Group)	DiD Estimate (β_3)	p-value	Effect Size
Promotion Rate	+8.5% (from 12% to 13.0%)	-0.2% (from 11.8% to 11.76%)	+0.087	0.03*	Cohen's d = 0.28
Average Appraisal Score (0-5)	+0.31 points	+0.05 points	+0.26	0.01*	Cohen's d = 0.35
Statistical Parity Difference	Reduced from 0.08 to 0.02	Remained at 0.07-0.09	-	0.04*	-
Equalized Odds (FPR Gap)	TPR Gap: Reduced by 60%	No significant change	-	0.02*	

Table 3 provides a technical audit of the system's fairness. It confirms that the smart contract reduced statistical disparities in how promotions were awarded and made the system's accuracy more equal across groups. However,

it also reveals that fairness wasn't perfectly achieved, and the system was least effective for LGBTQ+ employees who also belonged to racial minority groups, highlighting the complexity of intersectional bias.

Table 3. Key Findings from the Algorithmic Fairness Audit

Fairness Metric	Pre-Implementation Disparity	Post-Implementation Disparity	Bias Reduction	Notes
Statistical Parity (Promotions)	0.08 (Against LGBTQ+)	0.02	75%	Achieved near-parity in promotion rates.
Equalized Odds (TPR)	0.12 (Lower for LGBTQ+)	0.05	58%	Model accuracy became more equitable.
Predictive Parity (PPV)	0.10 (Lower for LGBTQ+)	0.06	40%	Improvement, but significant gap remains.
Intersectional Analysis (LGBTQ+ & Race)	Highest disparity for racial minorities (0.15)	Disparity reduced but persisted (0.08)	47%	Highlights the need for targeted design.

Table 3 captures the human experience behind the numbers. Employees felt the new system was more consistent and guard against favoritism, but they also found it impersonal and cold. While they appreciated the fairness, they missed the human empathy and context, and many expressed significant anxieties about their private data being permanently locked on an immutable ledger [26].

Table 4. Summary of Qualitative Themes from Case Studies & Interviews

Theme Category	Key Finding	Representative Quote (LGBTQ+ Employee)
Procedural Justice	Increased Perception of Fairness: The immutable, rule-based process was seen as a guard against managerial bias.	"For the first time, I felt the rules were the same for everyone. You can't just move the goalposts for people you like."
Interactional Justice	Mixed Feelings on "Dehumanization": Appreciation for reduced bias was tempered by concerns over the lack of human nuance and context.	"It's fairer, but it feels cold. There's no one to explain the 'why' behind the decision in a compassionate way."
Privacy & Trust	High Anxiety: Significant concern about who could access the immutable ledger and the potential for exposing LGBTQ+ status.	"Knowing that my data is locked forever on a system I don't understand is terrifying. What if it's hacked or used against me?"
Implementation Challenge	Resistance from Middle Management: Managers reported a loss of discretionary power and difficulties adapting to the rigid, encoded rules.	"My ability to advocate for my team based on unique circumstances has been completely taken away by this code."

Table 4 outlines the privacy trade-offs we identified. Our assessment found that while we could lower some risks—like limiting what data was stored on the blockchain—the core conflict with the "right to be forgotten" remained a serious, unresolved issue. The system improved transparency but created a new set of data protection challenges.

Table 5. Results from the Privacy Impact Assessment (PIA) Framework

PIA Criteria	Risk Level (Pre-Implementation)	Risk Level (Post-Mitigation)	Key Mitigation Strategy Applied
Data Minimization / On-Chain Exposure	High	Medium	Hybrid architecture successfully implemented; only hashes stored on-chain.
Right to Erasure (GDPR Compliance)	Critical	High	Risk remains high due to immutable hashes; key deletion for off-chain data was the primary mitigation.
Special Category Data (LGBTQ+	Critical	Medium	Strict access controls and pseudonymization reduced risk, but

Status)			linkability concerns persisted.
Transparency & Explainability	Medium	Low	The provision of a user-friendly audit trail dashboard significantly improved perceived transparen

Table 6 brings all the findings together to tell the complete story. It shows that the smart contracts were objectively effective at reducing bias and were perceived as fairer in their procedures. However, this came at a cost: the systems were seen as dehumanizing, and the privacy concerns were a major source of distrust, creating a complex trade-off between different aspects of fairness and well-being.

Table 6. Integrated Mixed-Methods Findings on Key Constructs

Construct	Quantitative Result	Qualitative Context	Integrated Conclusion
Effectiveness in Bias Reduction	Significant improvement in promotion rates and fairness metrics (Tables 1 & 2).	Confirmed by perceptions of increased procedural fairness (Table 3).	Smart contracts are effective at reducing procedural bias, leading to more equitable outcomes.
Organizational Justice	N/A	Strong procedural justice, weak interactional justice (Table 3).	The systems promote consistency at the cost of empathy and human touch, creating a justice trade-off.
Privacy-Perception Gap	PIA showed high/residual risk (Table 4).	Interviews revealed intense anxiety and distrust (Table 3).	Tec

4.1. Result Analysis

The qualitative and quantitative data integrated analysis promotes a subtle image of the impact of the smart contract system. The DiD estimates, and fairness audits are good quantitative indications of the effectiveness of the intervention in lessening procedural bias. The statistically significant positive change in the rate of promotion ($\beta 3 = 0.087$, $p=0.03$) and the score of appraisal among the LGBTQ+ workers in the treatment condition as well as the 75% decrease in the statistical parity difference proves that the rule-based, automated system was able to reduce certain discriminative results of the traditional appraisal procedure. This is also affirmed by the Algorithmic Fairness Audit which demonstrates significant gains in equalized odds, meaning that the accuracy of the model was more fair across groups [27]. Nevertheless, the existence of a predictive parity gap, as well as the significant, albeit less significant, intersectional disparities, indicate that the system is not fair across the board. These quantitative benefits were reflected in qualitative ones, since the employee perceptions of increased procedural justice were indicative of the inability of the management to act whimsically as the immutable and transparent nature of the smart contracts was perceived as a fortification of procedural justice. However, this was offset by the fact that there were very serious issues raised on the subject of interactional justice, as employees termed the practice as cold and dehumanizing, and it raised a lot of apprehension about the privacy implications of an invariable ledger, an issue that can be justified by the high amount of residual risks that the PIA framework has identified especially with regard to the right of erasure brought about by the GDPR [28].

5.Discussion

This research will be the first empirical data that smart contract-based systems can result in a powerful instrument regarding the reduction of bias in the LGBTQ+ employee appraisal and promotion. The results indicate that the procedural injustice which is one of the primary causes of bias in the literature could be directly remedied by encoding clear and consistently used rules into an unchangeable ledger [8], [10]. The high increase in the promotion rates and fairness indicators is consistent with the theoretical assertions that auditability and deterministic execution through blockchain can limit the subjectivity of discretion and decrease arbitrary variations in outcomes [2], [7].

Nevertheless, the findings are critical of the optimistic discourse of HR automation. To start with, there is the trade-off between procedural and interactional justice which is a significant finding. The system made the treatment consistent, but it also eliminated the human compassion and situational sense that employees relate to fair treatment [6, 10]. This implies that the aspect of fairness is multi-dimensional to the employees and that a relatively limited perspective on procedural measures is not enough to promote holistic organizational justice. Second, there is the privacy paradox. On the one hand, the technology was intended to create transparency but on

the other hand, it created a deep-rooted mistrust and fear of the same employees it was meant to safeguard, especially LGBTQ+ employees who feared that the sensitive identity information would be stored permanently on record [9], [14]. This affirms the legal scholarship that cautions a basic contradiction between immutability and data protection legislation [14], which our PIA framework can detect yet to some extent does not completely address using existing hybrid architectures.

Moreover, the gradual intersectional gaps and the un-sealed predictive parity gaps point to the fact that technological solutions do not suffice to eliminate the deeply rooted social prejudices. A smart contract is just as non-partisan as the laws it codifies, and the history it can be based on [7], [8]. The first requirements themselves may be unjust as well as the training data on which any integrated AI will be based may contain biases, thus the system will only be automated and will perpetuate the biases [8]. This explains the absolute importance of the participatory design workshops that we emphasize in our methodology to make sure that the rules per se are outlined with and by the LGBTQ+ employees [13].

5.1. Theoretical and Practical Implications

In theory, this work contributes to the sociotechnical systems theory by showing that the equity of technological interventions cannot be assessed only based on their output measures but also based on how they engage with the social and organizational mechanisms. The contrast between the increase in the objective results and the decrease in the subjective trust and empathy points to the complexity of the application of justice to automated systems.

In practice, this study provides organizations with a well-defined, empirically grounded recommendation, namely, smart contracts may become a component in the solution to bias, but not a panacea. Implementation should be accompanied by a strong change management that will handle employee fears and resistance by managers. Most importantly, they will have to spend lots of money on the complementary measures that enhance interactional justice like education of the managers on how to justify automated decisions in an empathetic manner and keeping their human appeal channels open. To policymakers, the conclusions indicate that there is an urgent need to shed light on regulation frameworks regarding immutable ledgers and the right to be forgotten, to offer legal assurance to organizations that want to innovate in a responsible manner [9], [14].

5.2. Limitations of Research

This study has limitations. Although it is a large sample, it was selected among those organizations that were already interested in solving bias, which may restrict generalization. The 12 months intervention period was adequate to indicate the initial effects but it is too little to measure the long term effects on career tracks and retention.

6.Conclusions

The study offers a mixed-method evaluation of the efficacy of smart contracts in curbing prejudice towards LGBTQ+ workers in appraisal and promotion frameworks. The findings confirm that hybrid-designed smart contracts with transparent rule-coding have the potential to become a powerful instrument of enhancing procedural justice and yield quantifiable change to discriminative outcomes [16]. The quasi-experimental results showed that the promotion rates and the fairness indicators of the LGBTQ+ employees have substantially increased, which proves the simple hypothesis that the biased managerial discretion might be constrained through the automation and irreversibility of the decision making process [29].

However, the crucial thing about the study is that this technical solution presents a complex of sociotechnical trade-offs. The disinterestedness and objectivity as the primary features of procedural fairness are the very elements that bring a significant risk to the interactional justice, employee privacy, and compliance with the regulations. Minimization bias hunt cannot be solved through technology alone, but through a comprehensive approach that will add a wise system design with a strong organizational change management, participatory design inclusiveness [13], and an unblinded insight into the inherent conflict with the data protection systems [14]. Smart contracts are not a silver bullet, but, perhaps, a discontinuous tool, the effectiveness of which is wholly reliant on its use in a bigger investment in equity, privacy, and human dignity [30].

6.1. Future Direction of Research

Based on the findings and limitations of this study, several critical pathways for future research emerge:

6.1.1. Advanced Privacy-Preserving Architectures:

It is of urgent need to go beyond hybrid architecture and experiment with the advanced cryptographic methods in the real-life situation of HR. The future research should be on the implementation and testing of zero-knowledge proofs (ZKPs) and payroll and promotion triggers [11], and secure multi-party computation to aggregate performance data, which may help balance auditability with strong data minimization and right to erasion.

6.1.2. Longitudinal and Intersectional Studies:

The studies should go beyond 12-month periods and explore how these systems have a long term effect on the career growth, employee retention and culture within the LGBTQ+ community. In addition, specific intersectional

effects need to be modelled and analysed in larger-scale, dedicated studies that formulate particular fairness constraints, and design principles to employees who are multiple marginalised identities [9].

6.1.3. Human-AI Interaction for Organizational Justice:

One possible way forward is the creation and trial of human-in-the-loop interfaces and explainability options that alleviate the dehumanizing impacts of automation. The research area is to understand the way to improve interactional justice in blockchain systems, such as creating standardized and compassionate communication codes that automated decisions learn or establishing efficient and transparent methods of human appeal [17].

Acknowledgements

This work is supported by Swami Vivekanand Subharti University, Meerut, India.

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