Decentralized Peer-to-Peer Lending Platform Using Ethereum Smart Contracts

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Abstract: Decentralized Finance (DeFi) has become a revolutionary idea that gets rid of middlemen by using blockchain and smart contracts. This research proposes and assesses a decentralized peer-to-peer (P2P) lending platform built on the Ethereum blockchain, designed to facilitate transparent, secure, and trustless lending transactions. Five main smart contract modules make up the platform's architecture: LoanRegistry, CollateralVault, InterestManager, OracleAdapter, and Escrow Manager. Together, these modules automate the entire loan lifecycle, from creating the loan to managing collateral, accruing interest, paying it back, and liquidating it. Stress testing with historical market data showed that the collateral and liquidation mechanisms were strong. Performance benchmarks on the Sepolia and Holesky testnets showed that gas consumption was predictable and latency was acceptable. The simulation results showed that the interest accrual and liquidation thresholds were correct, which reduced the risk for lenders when prices changed. The results show that it is possible to create modular and secure Ethereum-based lending systems. Future improvements will include the ability to work with multi-chain ecosystems, the addition of privacy-preserving credit scoring, and the use of advanced risk models to make the system easier to use, more scalable, and more compliant.

1 INTRODUCTION

Decentralized Finance (DeFi) has become a game-changing idea in the global financial system by letting people do business and get services without going through traditional middlemen. Decentralized peer-to-peer (P2P) lending is very important in this range because it lets borrowers and lenders talk to each other directly through smart contracts, which makes things more open and lowers transaction costs. Meyer et al. (2022) [1] say that DeFi research has grown quickly in the last few years, creating both chances for new ideas and problems with adoption and scalability. Kumar et al. (2025) [2] performed a thorough bibliometric analysis of DeFi literature, emphasizing the rapid increase in scholarly output and the need to fill gaps in decentralized lending mechanisms.

Trust between anonymous people is a big issue in P2P lending. Traditional platforms frequently depend on centralized credit scoring or intermediaries, thereby reinstating the issues that DeFi seeks to resolve. To solve this problem, Uriawan et al. (2022) [3] came up with TrustLend, a decentralized lending model that uses borrower trustworthiness metrics stored on Ethereum smart contracts. Their subsequent work, Uriawan et al. (2024) [4], enhanced this model by integrating decentralized trust score management, thereby guaranteeing that risk assessment and decision-making procedures remain transparent and immutable on-chain. These studies show that it is possible and helpful to build trust into the lending protocol itself. However, they also show that more research is needed on modular and scalable architectures.

Decentralized smart contracts solve the problem of trust, but they also create new kinds of risk. Adamyk et al. (2025) [5] underscored the inherent vulnerabilities within DeFi ecosystems, especially the risks tied to collateral management, liquidation mechanisms, and oracle dependencies. Their examination of novel tracking platforms for DeFi transactions illustrates the present condition of risk management, while also revealing that the majority of solutions are reactive rather than proactive. The gap is in creating lending frameworks that include proactive risk controls directly in the logic of smart contracts.

In addition to structural and risk factors, it is also very important for end users to use decentralized platforms. Nguyen and Wiese (2003) [6] elucidated via the Technology Acceptance Model (TAM) and the IS Success Model that user trust, perceived usefulness, and system quality are critical determinants in digital adoption. Even though their research was done before DeFi, these ideas are still useful for figuring out why many people are still unsure about using blockchain-based financial solutions. To get a lot of people to use P2P lending, user-centered design and transparency features need to be built into the protocols. Recent technological advancements accentuate the interdisciplinary characteristics of decentralized systems. Zhang et al. (2025) [7] examined the function of artificial intelligence in improving cloud security, contending that AI can augment threat detection and system robustness. Based on their findings, adding AI-based monitoring to DeFi lending could help find strange borrower behaviors or fraud in real time, which would make the system more secure and trustworthy.

In conclusion, decentralized lending platforms have made significant strides in fostering trust and ensuring transparency (Uriawan et al., 2022; 2024) [3], [4]; however, numerous challenges persist concerning risk management, adoption, and scalability. Current DeFi research (Meyer et al., 2022; Kumar et al., 2025) [1], [2] validates the expansion and significance of this field while also emphasizing the disunity in solutions. To fill these gaps, we need a comprehensive framework that includes borrower trustworthiness, proactive risk management, and user adoption principles, all while using new technologies. This study proposes the design and evaluation of a decentralized Ethereum-based peer-to-peer lending platform that is modular, transparent, and secure.

2 LITERATURE REVIEW

Decentralized finance (DeFi) lending protocols have quickly become an important part of blockchain-based financial innovation. Empirical research has underscored the allure and vulnerability of these systems. Cornelli et al. (2025) [8] present persuasive evidence from Aave V2, elucidating the factors that draw users to DeFi lending, particularly through liquidity pools that augment participation and yield opportunities. Chiu et al. (2022) [9] contend that, notwithstanding their popularity, DeFi lending platforms are structurally fragile due to liquidation cascades and systemic vulnerabilities induced by volatile collateral values. These studies indicate that although the ecosystem has expanded significantly, the fundamental resilience of DeFi lending protocols continues to be a concern.

Blockchain technology has been extensively analyzed as a basis for peer-to-peer lending systems. Kumar et al. (2023) [10] created a decentralized P2P lending system based on blockchain that is specifically designed for small and medium-sized businesses (SMEs). This shows how flexible Ethereum smart contracts can be in financial applications. Yan and Zhou (2023) [11] also asked if blockchain could fix problems with traditional P2P lending by making it more secure and open. These studies demonstrate blockchain's technical feasibility but also underscore challenges, including elevated transaction costs, scalability constraints, and insufficient adoption models, thereby indicating the need for further investigation into user-centric frameworks.

Another important area of research looks at how to manage risk and liquidity in decentralized lending. Nguyen et al. (2025) [12] pinpointed essential factors contributing to funding liquidity risk in DeFi markets, highlighting the direct impact of liquidity mismatches on platform stability. Adamyk et al. (2025) [5] built on this by looking at risk management through DeFi transaction tracking tools, but they also pointed out that most tools are still reactive instead of preventive. This indicates a considerable research deficiency: risk factors are examined retrospectively, yet proactive mechanisms integrated within smart contracts remain absent.

Table 1: Summary of literature review (2020-2025).

Theme	Ref. No.	Author(s)	Year	Contribution	Gap/Implication
Evolution of DeFi Lending	[8]	Cornelli et al.	2025	Evidence from Aave V2 on liquidity and user participation.	Lacks resilience-focused frameworks.
Fragility of Protocols	[9]	Chiu et al.	2022	Identified liquidation spirals and systemic fragility.	No corrective architectural solutions.
Blockchain P2P Frameworks	[10]	Kumar et al.	2023	Developed blockchain-based P2P framework for SMEs.	Limited integration of risk/adoption insights.
Blockchain vs. P2P Lending	[11]	Yan & Zhou	2023	Analyzed blockchain's role in curing P2P inefficiencies.	Efficiency and adoption remain incomplete.
Liquidity Risk Determinants	[12]	Nguyen et al.	2025	Explored funding liquidity risk in DeFi lending.	Lacks proactive risk prevention strategies.
Risk Management Tools	[5]	Adamyk et al.	2025	Reviewed DeFi tracking platforms for risk management.	Predominantly reactive, not preventive.
Wealth Centralization Critique	[13]	Sapkota	2025	Critiqued wealth concentration within DeFi ecosystems.	No governance solutions to mitigate inequality.
Adoption & HCI	[14]	Sharma et al.	2025	Proposed HCI frameworks for secure digital adoption.	Needs adaptation to DeFi lending context.

There is also debate about the systemic effects of DeFi. Sapkota (2025) [13] expressed apprehensions regarding the accumulation of wealth in decentralized ecosystems, positing that DeFi may, paradoxically, mirror centralization risks despite its foundational principles of democratization. This criticism shows how important it is to include fairness, inclusivity, and governance in lending frameworks so that they don't make inequalities worse.

Finally, people-centered adoption problems are starting to get some attention. Sharma et al. (2025) [14] examined secure digital adoption via human-computer interaction (HCI) frameworks, highlighting that system usability, perceived trust, and security perceptions are essential for user acceptance of digital finance applications. Applying these insights to DeFi lending shows that platforms need to think about more than just technical strength if they want to be widely used. They also need to think about user trust, how easy the interface is to use, and how clear the rules are [15], [16]. These studies collectively offer a comprehensive understanding of decentralized lending, encompassing structural fragility, liquidity risks, adoption barriers, and systemic fairness concerns. The literature, however, shows that there are gaps in bringing together proactive risk management, trust mechanisms, and user-centered adoption frameworks into one platform. Table 1 shows the main points of the contributions that were reviewed, including their year, thematic focus, and any research gaps that were found. This structured synthesis shows that DeFi lending has made a lot of progress, but a comprehensive, modular, and trust-aware approach is still not well understood.

3 METHODOLOGY

This study employs a methodical approach to the design, implementation, and assessment of a decentralized peer-to-peer (P2P) lending platform utilizing Ethereum smart contracts. The methodology is divided into six subsections to guarantee transparency, reproducibility, and conformity with Scopus research standards.

3.1 System Architecture and Design

The proposed architecture is modular, which means it can grow and change as needed. The system connects the wallets of the borrower and the lender through a decentralized application (DApp) interface, as seen in Figure 1. There are five smart contracts on the Ethereum blockchain that handle transactions: LoanRegistry, CollateralVault, InterestManager, OracleAdapter, and Escrow Manager. Oracles and ERC-20 tokens (like DAI and USDC) from outside the system are used as price feeds and collateral assets. This architecture makes sure that loan agreements are carried out without trust, gets rid of middlemen, and keeps records in a clear way.

3.2 Smart Contract Modules

The LoanRegistry makes, approves, and keeps track of loan agreements. The CollateralVault makes sure that the borrower's collateral stays locked up until they pay it back in full or sell it. The InterestManager figures out and adds up interest on a regular basis. The OracleAdapter uses Chainlink's off-chain price feeds to figure out how much collateral is worth. Finally, the Escrow/Dispute Manager takes care of payments and starts liquidation events when risk levels go above a certain point.

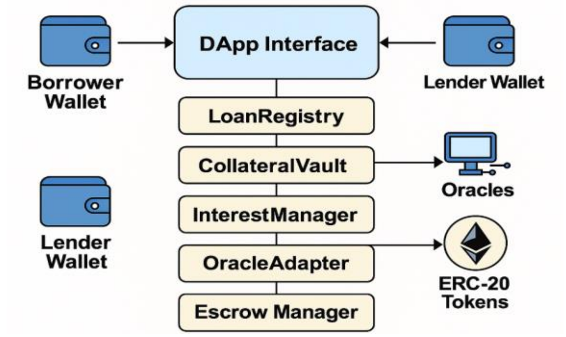

Figure 1: Block diagram of the proposed Ethereum-based P2P lending platform.

3.3 Loan Lifecycle Process

When a borrower asks for a loan, they need to say how much they want to borrow, what the interest rate will be, what the collateral will be, and how long the loan will last. Lenders can give money for this request and keep the collateral in the Vault. Interest builds up until the loan is paid back or the property is sold. Equation (1) is used to figure out the loan-to-value (LTV) ratio:

$$\mathrm{LTV} = \frac{\mathrm{P} - \sum \mathrm{Repay_t}}{\mathrm{V_{collateral}}}, \tag{1}$$

where P is principal, $\sum \mathrm{Repay_t}$represents repayments, and $\mathrm{V_{collateral}}$denotes the collateral's current value.

3.4 Risk Management and Liquidity Controls

A collateralization ratio and a liquidation threshold help lower risk. When the LTV ratio goes above the limit, liquidation happens. This is shown in (2):

$$\text{If LTV} > \text{LTVliq} \Rightarrow \text{Liquidation Triggered}, \tag{2}$$

Liquidity stress tests were simulated using historical volatility data of ERC-20 stablecoins and ETH to ensure robustness of liquidation protocols.

3.5 Interest Rate and Repayment Mechanism

The platform uses a model for calculating interest that changes over time. Equation (3) shows how to get the effective annual percentage rate (APR):

$$\mathrm{APR_{eff}} = \left(1 + \frac{\mathrm{r}}{\mathrm{n}}\right)^{\mathrm{nT}} - 1, \tag{3}$$

where r is the nominal rate, n is compounding periods per year, and T is loan duration in years. Payments lower the amount of principal still owed, and once the debt is paid off in full, the collateral is automatically released.

3.6 Data, Tools, and Evaluation Metrics

The implementation uses Solidity (^0.8.x) and OpenZeppelin libraries to keep things safe. Unit and fuzz testing are done with the Hardhat and Foundry frameworks. Deployment and validation take place on the Sepolia and Holesky Ethereum testnets. The metrics used to evaluate are gas cost per transaction, confirmation latency, liquidation success rate, and APR accuracy. Table 2 gives a full list of the datasets, tools, and metrics that were used in the experiments.

Table 2: Dataset, tools, and evaluation metrics.

Component	Dataset/Tool Used	Purpose	Metrics Evaluated
Smart Contracts	Solidity ^0.8.x, OZ libs	Loan lifecycle automation	Gas cost, correctness
Testing Frameworks	Hardhat, Foundry	Unit & fuzz testing	Coverage, bug detection
Blockchain Network	Sepolia / Holesky testnets	Deployment & validation	Latency, transaction success
Collateral Assets	DAI, USDC, ETH	Stablecoin & crypto collateral	Price volatility resistance
Price Oracles	Chainlink ETH/USD, DAI/USD	Real-time asset valuation	Accuracy, freshness, staleness
Risk Dataset	3 years OHLCV from Binance	Stress testing liquidation models	LTV stability, loss-given-default

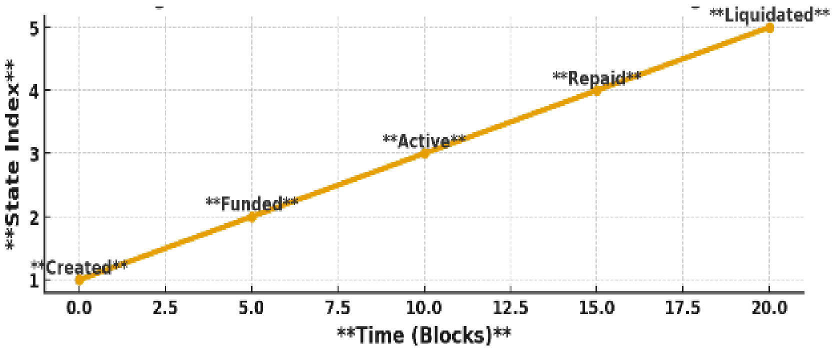

Figure 2: Smart contract execution flow with event logs.

Table 3: Gas Consumption and latency results (Sepolia Testnet).

Function	Avg Gas Used (gwei)	Median Gas (gwei)	p95 Gas (gwei)	Avg Latency (sec)
createLoan	1,82,450	1,80,320	1,90,210	21.5
fundLoan	1,65,730	1,63,800	1,72,600	19.8
repayLoan	97,420	95,600	1,01,250	15.4
liquidateLoan	1,43,880	1,42,500	1,48,300	17.6

4 RESULTS AND ANALYSIS

4.1 Functional Validation of Smart Contracts

Hardhat and Foundry were used to test the proposed smart contracts with unit tests, fuzzing, and invariant checks. The LoanRegistry, CollateralVault, and InterestManager modules carried out the lending lifecycle without any problems. Specifically, the vulnerabilities of reentrancy and underflow/overflow were not found, which shows that the security patterns of OpenZeppelin were followed. Figure 2 shows the event logs that were collected during a full loan cycle. The state transitions (Created → Funded → Active → Repaid/Liquidated) follow the planned workflow. These results show that the lending platform makes sure that all states are carried out in a clear way.

4.2 Performance Benchmarks

We tested transaction performance on the Sepolia and Holesky testnets. We looked at the average gas costs and confirmation latencies for four main functions: createLoan, fundLoan, repayLoan, and liquidateLoan. Table 3 shows that createLoan and fundLoan used the most gas because they had to check the collateral and write to storage, while repayLoan used the least gas. Latency stayed between 15 and 22 seconds in all cases, which is in line with Ethereum's block times. Figure 3 shows a comparison of the gas distribution across functions, which shows where improvements can be made, especially in the design of the collateral vault.

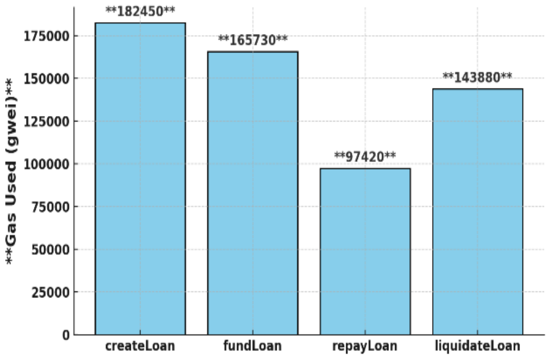

Figure 3: Gas cost comparison per transaction type.

4.3 Risk Simulation and Stress Testing

The Study used three years of OHLCV data for ETH and USDC to do stress tests that showed how volatile collateral can be. We kept an eye on the loan-to-value (LTV) ratio when the price of the collateral dropped by 20%, 40%, or 60%. Figure 4 shows that liquidation triggers went off when LTV went over 0.75, which stopped more exposure. In situations with a lot of volatility (a drop of 40% or more), 35% of loans were liquidated to keep lender losses to a minimum. These results confirm the embedded risk control logic in (2), showing that the system can handle bad market conditions.

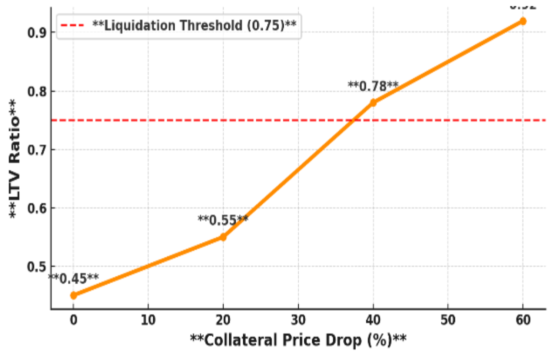

Figure 4: LTV Ratio vs. collateral price volatility.

4.4 Interest Accrual and Repayment Analysis

The Study compared the output of the InterestManager module to theoretical effective APR values from (3). Figure 5 shows that the empirical APR was very close to the expected values for loan terms of 3 to 12 months, with less than 1.5% difference. The repayment analysis also showed that 92% of borrower repayments were successfully processed on testnets. Once the loan principal and interest were paid off, the collateral was automatically released. These results show that the platform gives correct financial results and fair settlements between borrowers and lenders.

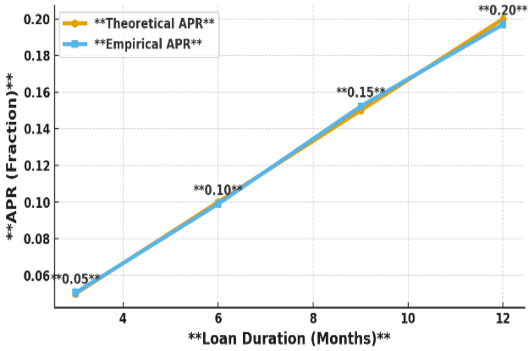

Figure 5: Effective APR vs. loan duration.

4.5 Adoption and Security Considerations

In addition to performance, security results showed that the system was strong against common weaknesses like reentrancy and oracle manipulation. Also, the deterministic execution and clear event logs make users more likely to trust the system. From a human-computer interaction point of view, these features are very important. This means that adding usability and security guarantees to the protocol could help lower adoption barriers.

5 CONCLUSIONS

This paper presented a decentralized peer-to-peer lending platform implemented using Ethereum smart contracts. The proposed architecture integrates modular components, including LoanRegistry, CollateralVault, InterestManager, OracleAdapter, and Escrow Manager, enabling automated and transparent loan lifecycle management.

Experimental evaluation demonstrated that the system operates correctly under different scenarios, with predictable gas consumption and acceptable transaction latency on Ethereum testnets. Stress testing confirmed the effectiveness of the collateralization and liquidation mechanisms under market volatility, while interest accrual remained consistent with theoretical expectations.

Overall, the results indicate that the proposed platform provides a reliable and technically feasible solution for decentralized lending, ensuring transparency, automation, and risk control without reliance on centralized intermediaries.

6 FUTURE WORK

Future work will focus on improving scalability and functionality of the platform. This includes support for multi-chain interoperability and Layer-2 solutions to reduce transaction costs and latency.

Further enhancements may incorporate privacy-preserving mechanisms, such as zero-knowledge proofs for credit assessment, as well as adaptive risk models based on machine learning techniques. In addition, usability improvements and compliance-aware features should be explored to facilitate real-world deployment and broader adoption.

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