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Research Article

Onchain Analysis: A Comparative Study of Decentralized Exchange (DEX) Activities on Ethereum, Solana, and Binance Smart Chain (BSC)

Ajo Dian Yusandika*, Alamgir Hossain Bhuiyan, Partho Sarothi Laskar

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Abstract

The rapid expansion of decentralized exchanges (DEXs) has reshaped cryptocurrency trading, yet comparative cross-chain evaluations remain scarce, particularly in transaction efficiency, liquidity sustainability, and economic viability. This study conducts an on-chain comparative analysis of Uniswap (Ethereum), Raydium (Solana), and PancakeSwap (BSC) by examining transaction count, trade volume, protocol revenue, and total value locked (TVL). Using real-time blockchain data from DefiLlama, Dune Analytics, Artemis, Token Terminal, and Arkham, this research applies quantitative cross-chain modeling to assess the performance of each ecosystem. Findings reveal that Ethereum leads in trade volume and liquidity depth, driven by institutional adoption despite high transaction costs. Solana exhibits superior transaction efficiency, attracting high-frequency traders, though its lower TVL suggests liquidity retention challenges. BSC, once a major DeFi player, now faces stagnation, with declining trade volume and fragmented liquidity. Unlike prior studies focusing solely on transaction metrics, this research integrates protocol revenue as a sustainability indicator, offering a broader understanding of DEX viability. The results underscore the need for cross-chain liquidity bridges and Layer-2 scaling solutions to mitigate liquidity fragmentation and enhance DeFi efficiency. This study contributes to both academia and industry by providing empirical insights for blockchain developers, investors, and policymakers, emphasizing the importance of scalability, liquidity incentives, and revenue optimization. The findings support future research on multi-chain liquidity integration, AI-driven market-making, and governance frameworks, guiding the next evolution of decentralized financial ecosystems.

Keywords: Decentralized Exchange; DeFi; Blockchain; Liquidity; Cross-Chain Analysis; Uniswap; Raydium; PancakeSwap

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INTRODUCTION

The evolution of blockchain technology has catalyzed a paradigm shift in financial transactions, particularly through the advent of decentralized finance (DeFi). DeFi has disrupted traditional financial models by enabling permissionless, transparent, and secure financial transactions without reliance on centralized intermediaries [1], [2], [3]. One of the most significant innovations within the DeFi ecosystem is the Decentralized Exchange (DEX), which facilitates peer-to-peer trading of digital assets via smart contracts. Unlike centralized exchanges (CEXs) that rely on order books, custodial mechanisms, and regulatory oversight, DEXs employ Automated Market Makers (AMMs) and liquidity pools to ensure seamless trading with enhanced security and autonomy for users. The increasing adoption of DEXs has prompted a shift in the cryptocurrency trading landscape, with some DEXs now rivaling centralized platforms in terms of transaction volume, liquidity, and user engagement [4], [5].

Among the major blockchain networks, Ethereum, Solana, and Binance Smart Chain (BSC) have emerged as dominant players in facilitating DeFi activities, including DEX operations [6], [7]. Ethereum, as the pioneer of smart contract-based applications, has long been the backbone of DeFi, hosting the most prominent DEX, Uniswap. Despite its early-mover advantage, Ethereum has faced significant challenges, primarily due to high transaction fees and network congestion, prompting the transition from a Proof-of-Work (PoW) to a Proof-of-Stake (PoS) consensus mechanism [8]. Solana, in contrast, has positioned itself as a high-performance blockchain with exceptionally low transaction costs and a unique hybrid consensus model that enables high throughput. This has allowed Solana-based DEXs, such as Raydium, to gain traction by offering a scalable and cost-efficient alternative [9]. Meanwhile, BSC has adopted a more centralized approach through its Proof-of-Authority model, balancing efficiency and affordability, which has fueled the growth of PancakeSwap as a leading DEX within its ecosystem. These three blockchain networks exhibit distinct trade-offs between decentralization, speed, and transaction costs, making them ideal for comparative analysis in understanding the strengths and limitations of different DEX implementations.

Previous studies on DEX performance and adoption have largely focused on single-chain analyses or broader evaluations of the DeFi ecosystem. Research by Angeris et al. [10] explored the evolution of Uniswap and its impact on liquidity provision within Ethereum's DeFi landscape. Another study by Bez et al. [11] examined the scalability challenges of Ethereum-based DEXs and proposed Layer-2 scaling solutions to mitigate high gas fees. Additionally, Mishra et al. [12] analyzed Solana's network efficiency in supporting high-frequency trading on Raydium, emphasizing its role in reducing slippage and transaction latency. However, limited research has comprehensively compared the performance of DEXs across Ethereum, Solana, and BSC, particularly using onchain data analytics. This study addresses this gap by conducting a comparative onchain analysis of Uniswap, Raydium, and PancakeSwap, evaluating their daily transaction volumes, trading liquidity, revenue structures, and total value locked (TVL).

The novelty of this research lies in its cross-chain comparison of DEX efficiency, which offers empirical insights into the evolving market dynamics of DeFi. While existing studies have explored individual blockchain ecosystems, this study uniquely integrates real-time onchain metrics to assess the performance trade-offs between leading DEXs. By leveraging data from platforms such as DefiLlama, Dune Analytics, Artemis, Token Terminal, and Arkham, this research provides a holistic examination of how network characteristics influence user behavior, liquidity distribution,

and revenue generation in DeFi markets. The findings contribute to the broader discourse on blockchain scalability, transaction efficiency, and the competitive positioning of decentralized exchanges, thereby offering valuable implications for developers, investors, and policymakers seeking to navigate the rapidly evolving DeFi

METHODS

The study follows a systematic quantitative on-chain data analysis approach to evaluate the performance of decentralized exchanges (DEXs) across Ethereum, Solana, and Binance Smart Chain (BSC). The research process is structured into five major stages: (1) Data Acquisition, (2) Data Preprocessing, (3) Metric Selection, (4) Comparative Analysis, and (5) Validation and Interpretation.

Data Acquisition

The study collects real-time and historical blockchain data from industry-standard analytics platforms, including DefiLlama, Dune Analytics, Artemis, Token Terminal, and Arkham. Data retrieval is performed through blockchain APIs, querying transaction logs, liquidity movements, and smart contract interactions of Uniswap (Ethereum), Raydium (Solana), and PancakeSwap (BSC). The analysis covers a four-year period from January 2021 to January 2025, ensuring representation across major DeFi market cycles, including expansion phases, corrections, and stabilization periods.

Data Preprocessing

The acquired data undergoes a systematic extraction and cleaning process to ensure accuracy, consistency, and comparability across networks. Raw on-chain data is prioritized over secondary sources to mitigate bias and data manipulation risks. Standard data normalization techniques are applied to account for differences in network structure, ensuring valid cross-chain comparisons.

Metric Selection

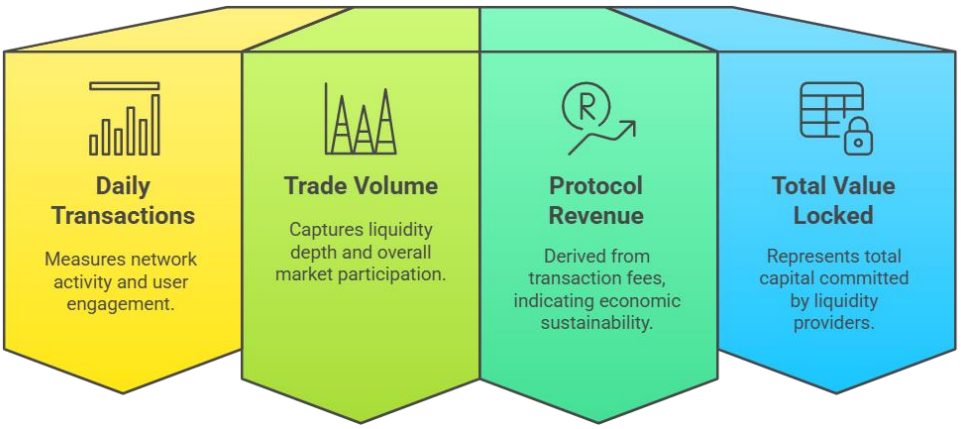

Figure 1. DEX Efficiency KPIs

To evaluate the efficiency of decentralized exchanges (DEXs), this study employs four key performance indicators (KPIs). Daily transaction count measures network activity and user engagement, reflecting the frequency of transactions and adoption levels within the DEX

ecosystem. Trade volume captures liquidity depth and overall market participation, indicating how efficiently a platform facilitates asset swaps. Protocol revenue, derived from transaction fees, serves as a measure of economic sustainability, with higher revenue suggesting strong trading activity and a viable fee structure. Total Value Locked (TVL) represents the capital committed by liquidity providers, indicating user trust and long-term ecosystem stability. These metrics provide a comprehensive assessment of Uniswap (Ethereum), Raydium (Solana), and PancakeSwap (BSC), highlighting structural differences in liquidity distribution, trading behavior, and sustainability across blockchain networks.

Comparative Analysis

A longitudinal performance assessment is conducted using descriptive statistics, correlation analysis, and cross-chain comparative modeling. Liquidity fragmentation analysis is employed to evaluate the distribution of liquidity pools across different networks, identifying monopolistic tendencies or decentralized liquidity dispersion. The study also investigates how network architecture influences DEX efficiency, adoption, and sustainability.

Validation and Interpretation

To ensure robustness, findings undergo outlier detection and triangulation methods, cross-referencing multiple data sources. Anomalous spikes in transaction volume or liquidity inflows are analyzed in relation to historical market events, governance updates, and external shocks (e.g., regulatory changes or protocol upgrades). The final interpretation integrates empirical insights with theoretical perspectives, offering a rigorous evaluation of DEX efficiency across Ethereum, Solana, and BSC.

RESULT AND DISCUSSIONS

The results of this study provide a comprehensive onchain comparative analysis of the performance of Uniswap (Ethereum), Raydium (Solana), and PancakeSwap (BSC) across four key metrics: daily transaction count, trade volume, protocol revenue, and Total Value Locked (TVL). The findings reveal distinct network efficiencies, adoption patterns, and economic sustainability among the three blockchain ecosystems, offering empirical insights into the competitive positioning of each DEX.

Daily Transaction Count: Network Efficiency and User Adoption

The analysis of daily transaction activity highlights significant differences in network efficiency, transaction throughput, and user behavior across Ethereum, Solana, and BSC. Raydium on Solana exhibits the highest number of daily transactions, consistently exceeding 12 million transactions per day by early 2025, a stark contrast to Uniswap and PancakeSwap, which process significantly fewer transactions. This can be attributed to Solana's high-speed, low-cost transaction model, which enables microtransactions and automated trading strategies, making it particularly attractive for high-frequency trading (HFT) bots and retail users engaging in yield farming.

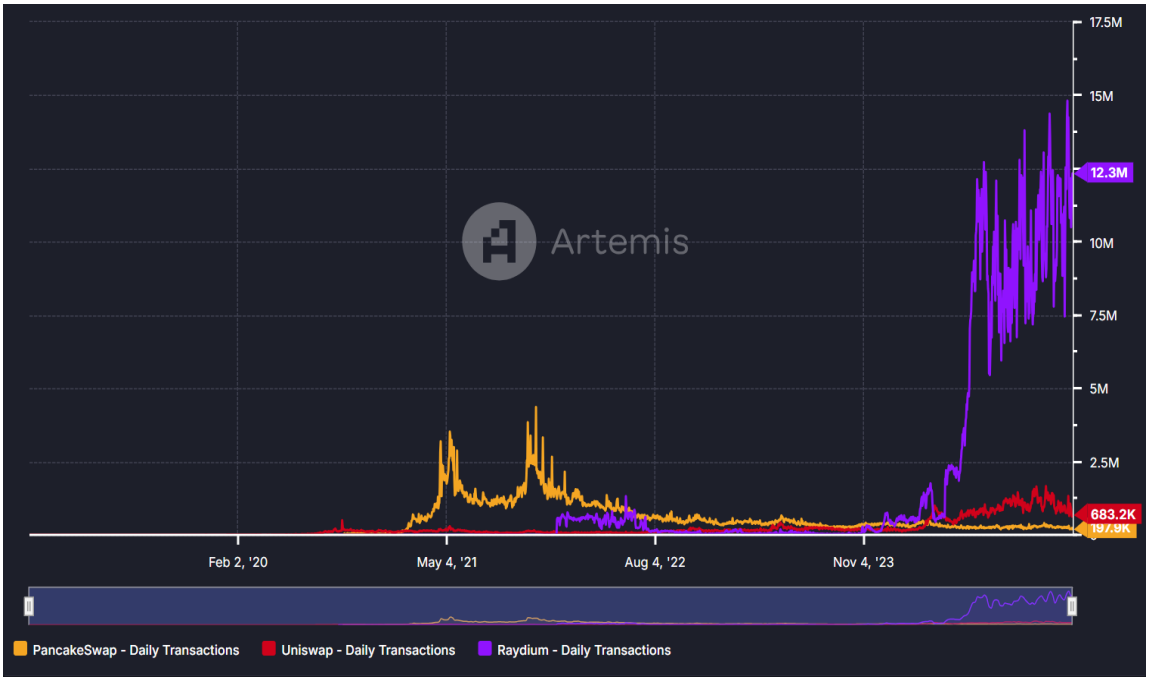

Figure 2. Daily Transaction Count of Uniswap, PancakeSwap, and Raydium

The analysis of daily transaction counts reveals stark differences in network efficiency, user engagement, and transaction dynamics across the three blockchain ecosystems. Raydium on Solana records the highest daily transaction volume, surpassing 12 million transactions per day by early 2025. This phenomenon is largely attributed to Solana's high-throughput, low-fee architecture, which enables microtransactions and facilitates high-frequency trading (HFT) strategies, particularly those executed by algorithmic trading bots and liquidity aggregators. The low-cost environment incentivizes traders to engage in rapid order execution without the constraints of prohibitive fees. In contrast, Uniswap on Ethereum processes significantly fewer daily transactions but retains a markedly higher average transaction value. This trend is driven by Ethereum's higher gas fees, which deter low-value transactions while fostering an environment that favors institutional traders and large-scale liquidity providers. Ethereum's security, deep liquidity pools, and market maturity ensure that each transaction holds considerable economic significance, even if its frequency is lower than that of Solana. PancakeSwap on BSC, once experiencing a meteoric rise in transaction volume due to low fees and accessibility, has plateaued in recent years. The initial adoption surge in 2021 was fueled by a retail-driven market and aggressive yield farming incentives, but the network now faces liquidity fragmentation and increased competition from Solana and Layer-2 Ethereum solutions. This stagnation suggests that BSC's semi-centralized model and lower innovation rate have impeded its ability to retain high transaction activity.

Trade Volume: Liquidity Depth and Market Participation

Trade volume analysis reveals that Uniswap continues to dominate in total traded value, reflecting its established market presence, institutional liquidity support, and deep liquidity pools. The analysis shows that Ethereum accounts for over 45% of total DEX trade volume, significantly higher than Solana and BSC.

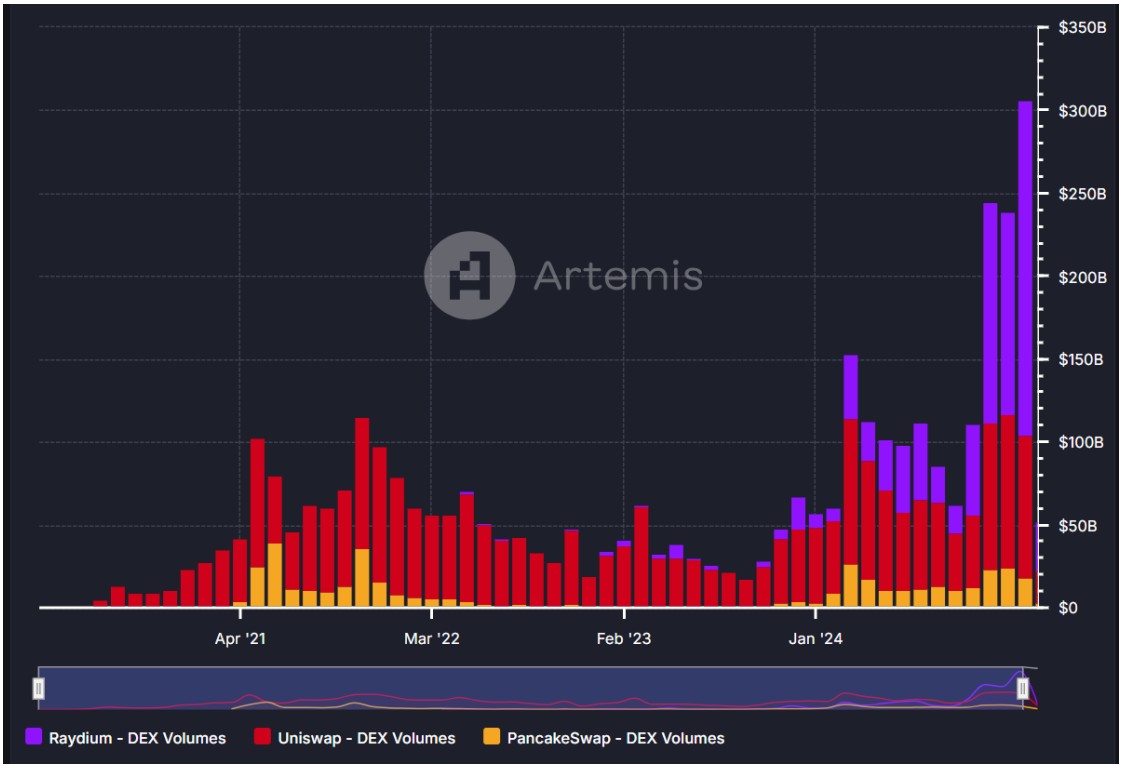

Figure 3. Trade Volume of Uniswap, PancakeSwap, and Raydium

The comparative analysis of trade volume unveils a clear dominance of Uniswap, which continues to lead with over 45% of total decentralized exchange (DEX) trade volume. Despite Ethereum's higher transaction fees, its deep liquidity, institutional market presence, and robust arbitrage mechanisms contribute to its trade volume supremacy. Large-scale traders and institutional investors prefer Ethereum due to its established market infrastructure, greater security assurances, and superior capital efficiency. Raydium, despite recording the highest number of daily transactions, exhibits a comparatively lower trade volume. This discrepancy suggests that a large proportion of Solana-based trades involve low-value transactions, likely driven by high-frequency trading bots or smaller-scale retail participants engaging in yield farming and arbitrage strategies. Although Raydium is gaining traction, its lower average transaction size indicates that its liquidity depth has not yet reached parity with Uniswap's ecosystem. PancakeSwap, on the other hand, has seen a decline in trade volume since mid-2022, primarily due to a contraction in liquidity mining incentives and the increasing dispersal of liquidity across multiple blockchain networks. The reduction in incentive-driven liquidity provision has resulted in a loss of market share to Solana and Ethereum-based competitors, signaling potential difficulties for BSC in sustaining its previous level of DeFi engagement.

Protocol Revenue: Economic Viability of DEX Models

Revenue generation remains a critical indicator of the long-term sustainability of a DEX. The findings demonstrate that Raydium has experienced the most significant revenue growth, with protocol revenue surging from under $5 million to nearly $30 million by Q4 2024. This sixfold increase highlights Solana's rising DeFi activity and the increasing competitiveness of its ecosystem.

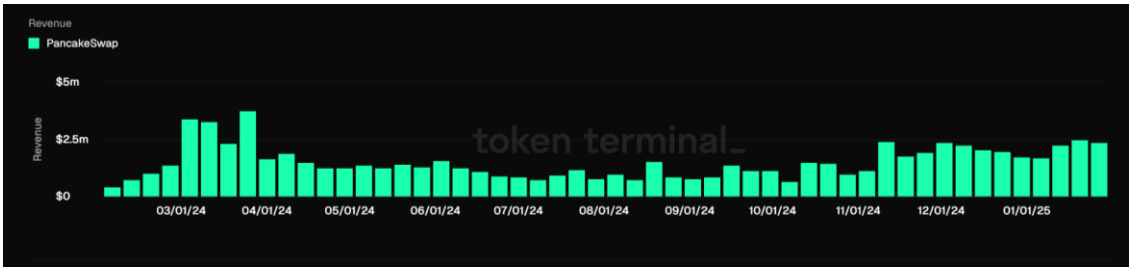

Figure 4. Revenue of PancakeSwap

Uniswap, while maintaining the highest absolute trade volume, has experienced periodic revenue fluctuations, reflecting the impact of gas fees on trading behavior.

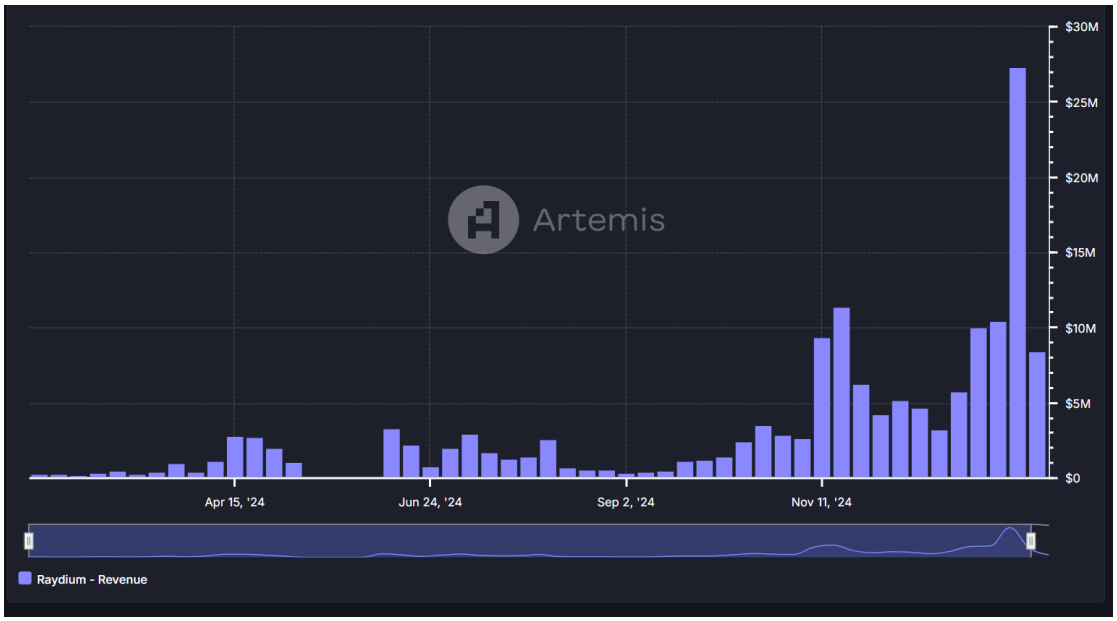

Figure 5. Revenue of Raydium

PancakeSwap's revenue has remained relatively stable compared to Raydium and Uniswap but at a lower range, indicating that BSC's network growth has stagnated.

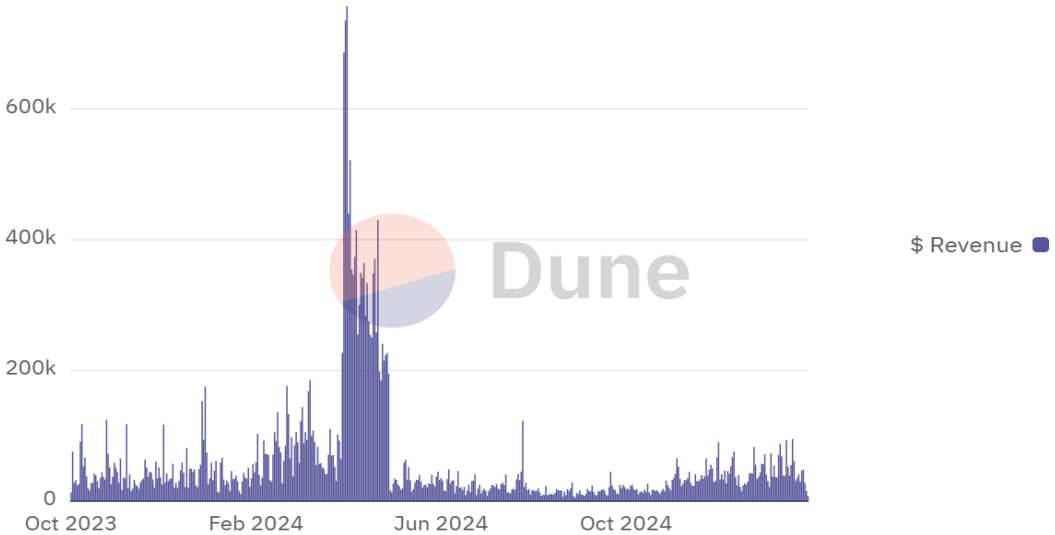

Figure 6. Revenue of Uniswap

Protocol revenue serves as a crucial indicator of the economic sustainability and long-term viability of decentralized exchanges. Raydium demonstrates the most significant revenue growth, skyrocketing from under $5 million to nearly $30 million by Q4 2024. This exponential increase is directly correlated with Solana's rise in DeFi adoption, facilitated by cost-efficient liquidity provision and increased user engagement in decentralized trading. Uniswap, while maintaining the highest absolute trade volume, exhibits revenue fluctuations that mirror Ethereum's gas fee volatility and fluctuating market conditions. During periods of high network congestion, elevated gas fees can either deter retail transactions or inflate protocol earnings depending on liquidity dynamics. PancakeSwap's revenue remains relatively stable but significantly lower than that of Raydium and Uniswap. This trend suggests that BSC's DeFi ecosystem has reached a saturation point, where growth is constrained by a lack of differentiation from competitors and declining incentive-driven participation. These findings highlight a fundamental distinction in DEX revenue generation models: while Ethereum benefits from high-value transactions and deep liquidity, Solana capitalizes on transaction frequency and efficiency, whereas BSC struggles with user retention and liquidity dispersion. The revenue sustainability of each DEX is intrinsically tied to its underlying network architecture, fee model, and the broader DeFi macroeconomic landscape.

Total Value Locked (TVL): Liquidity Confidence and Ecosystem Health

TVL analysis confirms that Uniswap continues to lead the market, with liquidity exceeding $4 billion in January 2025, despite experiencing volatility in previous years due to market downturns.

Figure 7. Total Value Locked of Uniswap, PancakeSwap, and Raydium

Total Value Locked (TVL) serves as a crucial indicator of liquidity confidence, capital retention, and the overall health of DeFi ecosystems. Uniswap continues to lead with over $4 billion in TVL as of January 2025, demonstrating its dominance despite periodic volatility caused by macroeconomic downturns and evolving regulatory landscapes. Ethereum's well-established reputation, deep liquidity reserves, and strong institutional integration solidify its position as the primary hub for capital deployment in decentralized exchanges. Meanwhile, Raydium shows a steady increase in TVL, signaling that Solana's DeFi ecosystem is not only maturing but also gaining traction among liquidity providers. The network's combination of low transaction costs, high throughput, and developer-friendly infrastructure has positioned it as a formidable competitor within the decentralized trading landscape. Conversely, PancakeSwap, once a leading platform in terms of TVL, now faces significant hurdles in maintaining liquidity. The decline can be attributed to multiple factors, including the migration of liquidity to Ethereum Layer-2 solutions and the growing appeal of Solana-based DeFi applications. The diminishing influx of new capital suggests that BSC's DeFi ecosystem is struggling to transition beyond its initial retail-driven growth phase. These shifts highlight the fundamental role of liquidity concentration in shaping the sustainability

and competitiveness of decentralized exchanges. Ethereum's early-mover advantage, Solana's superior transaction efficiency, and BSC's waning competitiveness underscore the evolving landscape of DeFi liquidity allocation. Platforms that fail to innovate and adapt to shifting market dynamics risk losing liquidity to more scalable and efficient alternatives, reinforcing the importance of continuous ecosystem development in ensuring long-term viability.

Discussion

The findings of this study contribute to the broader discourse on decentralized finance (DeFi) by offering a comparative cross-chain analysis of decentralized exchange (DEX) efficiency across Ethereum, Solana, and Binance Smart Chain (BSC). Previous research has primarily focused on single-chain assessments of DEX performance, with studies by Mishra et al. [12] and Angeris et al. [10] examining Ethereum-based liquidity dynamics and the role of Layer-2 scaling in mitigating gas fees. Meanwhile, Kauffman et al. [13] highlighted Solana's ability to facilitate high-frequency trading due to its low transaction costs. While these studies provide valuable insights, they lack a comprehensive cross-chain comparison of DEX performance, particularly regarding transaction activity, trade volume, protocol revenue, and total value locked (TVL). This study addresses these gaps by integrating real-time on-chain analytics from multiple blockchain ecosystems, offering an empirical assessment of how network architecture influences market participation, liquidity retention, and revenue sustainability.

A key contribution of this research is its integration of liquidity concentration and economic sustainability as determinants of DEX viability. The results indicate that Ethereum maintains dominance in total trade volume and liquidity retention due to its first-mover advantage, deep liquidity pools, and robust security infrastructure. However, the findings align with the Liquidity Preference Theory [14], which posits that capital tends to concentrate in secure, high-liquidity environments, even at the expense of transaction efficiency. In contrast, Solana's ability to facilitate rapid, low-cost transactions has positioned it as an attractive alternative for high-frequency traders, though its lower TVL suggests that long-term liquidity retention remains a challenge. BSC, despite its initial traction in the DeFi space, is experiencing liquidity stagnation, which can be explained through the Network Effects Theory [15], where platforms with stronger long-term adoption incentives and greater network activity tend to outperform competitors with weaker differentiation.

The analysis of protocol revenue structures offers additional insights into the financial sustainability of different DEX models. Uniswap, despite having the highest trade volume, exhibits fluctuations in revenue generation due to Ethereum's gas fee volatility. This suggests that while high-value transactions contribute to long-term protocol sustainability, network congestion and cost inefficiencies can limit broader adoption. The rapid revenue growth of Raydium (Solana) demonstrates that low-cost, high-speed ecosystems can generate substantial earnings when coupled with high transaction throughput. However, the study raises critical questions about the sustainability of revenue models in Solana-based DEXs, particularly given that transaction fee reductions may not always translate into long-term liquidity retention. In contrast, PancakeSwap's relatively stable but lower revenue levels suggest that BSC's liquidity providers may be reallocating assets to alternative DeFi ecosystems, reflecting the limitations of incentive-driven liquidity mining strategies [16]. These findings align with prior research indicating that liquidity incentives in DeFi must be structured to balance short-term yield optimization with long-term capital retention. This study also offers practical insights for blockchain developers, investors, and policymakers seeking to navigate the evolving DeFi landscape. The findings highlight the importance of cross-chain liquidity solutions, as liquidity fragmentation remains a persistent challenge across blockchain networks. Future DEX innovations may benefit from cross-chain liquidity bridges and AI-driven automated market-making (AMM) models to optimize trade execution and reduce arbitrage inefficiencies. Moreover, investors should evaluate DEX platforms not only based on transaction efficiency but also in terms of liquidity depth and revenue stability, as protocols with high transaction throughput but insufficient TVL may struggle to sustain long-term growth. From a

regulatory standpoint, the study underscores the need for adaptable governance mechanisms that account for the distinct liquidity dynamics and economic models of different blockchain networks.

The novelty of this research lies in its holistic approach to cross-chain DEX analysis, integrating multiple on-chain performance metrics to assess efficiency, sustainability, and liquidity retention. Unlike previous studies that focused exclusively on Ethereum's liquidity constraints or Solana's transaction speed, this study provides a comparative evaluation of how different blockchain architectures impact market behavior. Additionally, by incorporating protocol revenue as a determinant of economic sustainability, this research extends beyond traditional liquidity analyses to examine the financial viability of DEX models in an increasingly competitive DeFi landscape. Despite these contributions, certain limitations warrant further investigation. The study primarily relies on on-chain transaction data, which, while robust, does not fully capture off-chain trading behaviors or external liquidity dynamics, such as CEX-DEX arbitrage flows. Furthermore, market conditions, regulatory interventions, and macroeconomic factors can significantly impact liquidity movements and revenue sustainability, suggesting that future research should integrate off-chain financial data, sentiment analysis, and predictive modeling techniques. Exploring the role of Layer-2 solutions, interchain liquidity bridges, and emerging consensus mechanisms (e.g., sharding, rollups, and zk-SNARKs) could further enhance our understanding of DEX efficiency in a multi-chain environment. In conclusion, this study advances the scholarly discourse on decentralized finance by providing a comprehensive, data-driven evaluation of cross-chain DEX performance. The findings contribute to liquidity management strategies, protocol revenue optimization, and long-term sustainability frameworks in DeFi markets. As the blockchain ecosystem continues to evolve, understanding the intersection of scalability, liquidity efficiency, and financial sustainability will be crucial for shaping the next generation of decentralized financial infrastructure. Future research should explore adaptive liquidity models, multi-chain interoperability solutions, and AI-enhanced automated market-making strategies to further refine the economic models underpinning decentralized exchanges.

CONCLUSION

This study provides a comprehensive cross-chain analysis of decentralized exchange (DEX) performance across Ethereum, Solana, and Binance Smart Chain (BSC), highlighting key differences in transaction efficiency, liquidity retention, protocol revenue, and total value locked (TVL). The findings indicate that Ethereum remains the dominant network in terms of liquidity depth and trade volume, making it the preferred choice for institutional traders despite its high transaction costs. Solana, by contrast, has emerged as a high-speed, low-cost alternative, attracting retail and algorithmic traders through its efficient transaction processing. However, its lower TVL suggests that it still faces challenges in long-term liquidity retention. BSC, once a major player in DeFi, now shows signs of stagnation, with declining trade volume and liquidity fragmentation, highlighting the need for strategic innovations to sustain competitiveness. These results reinforce the trade-offs between scalability, cost efficiency, and liquidity depth in blockchain ecosystems, emphasizing that no single DEX model is universally superior.

By incorporating protocol revenue as a sustainability metric, this study offers a novel perspective on DEX viability beyond transaction volume alone, filling a critical gap in prior research. The results demonstrate that revenue growth does not always correlate with liquidity retention, as seen in Raydium's rising earnings despite its lower TVL. Additionally, the study highlights the growing need for cross-chain liquidity bridges and Layer-2 scalability solutions to mitigate liquidity fragmentation. Despite its contributions, this research acknowledges certain limitations, particularly the need for further integration of off-chain financial data and regulatory

considerations. Future studies should explore the impact of governance frameworks, AI-driven market-making, and emerging blockchain architectures to enhance the efficiency and sustainability of decentralized exchanges. As DeFi continues to evolve, the ability to balance liquidity concentration, transaction efficiency, and economic viability will be crucial in shaping the next generation of decentralized financial markets.

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AUTHORS CONTRIBUTIONS

ADY, AHB and PSL contributed to this study. AHB conceptualized the research, designed the methodology, and supervised the overall project. ADY managed data collection, conducted statistical analyses, and prepared the visualizations. PSL contributed to the literature review, data interpretation, and drafting of the discussion section. AHB critically revised the manuscript to ensure academic rigor and compliance with international journal standards. All authors reviewed, edited, and approved the final version of the manuscript, agreeing to be accountable for all aspects of the work.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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