

ENHANCING MOBILE CRYPTOCURRENCY WALLETS: A COMPREHENSIVE ANALYSIS OF USER EXPERIENCE, SECURITY, AND FEATURE DEVELOPMENT

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Abstract—The surge in cryptocurrency usage has increased reliance on cryptocurrency wallet applications. However, the usability, security, and feature richness of crypto wallets require significant enhancements. This research aims to identify critical factors that should guide the future design of mobile cryptocurrency wallets. The first step was to collect user reviews on several popular crypto wallets as the dataset. A total of 5,466 mobile wallet-related reviews from mobile application stores were filtered and analyzed. A machine-learning approach was used to cluster the user reviews. The analysis shows that customer issues are divided into four main themes: domain-specific challenges, security and privacy concerns, misconceptions, and trust issues. A software process assessment was also conducted to examine the current state of crypto wallets in terms of security, usability, and feature richness. Around 21 crypto wallet platforms were explored and assessed. Based on the thematic analysis and software process assessment, feature recommendations are proposed to address these shortcomings and enhance the credibility of mobile cryptocurrency wallets.

Keywords: Crypto wallet, software process assessment, thematic analysis, user experience.

Intisari—Peningkatan penggunaan mata uang kripto telah meningkatkan ketergantungan pada aplikasi dompet kripto (crypto wallet). Terlepas dari peningkatan yang ada tingkat usability, keamanan, dan kekayaan fitur dari dompet kripto memerlukan peningkatan yang signifikan. Penelitian ini bertujuan untuk mengidentifikasi faktor-faktor kritis yang dapat menjadi dasar dari rancangan masa depan dompet mobile. Langkah pertama adalah mengumpulkan ulasan pengguna terhadap beberapa dompet kripto populer sebagai dataset. Sebanyak 5,466 ulasan terkait dompet mobile dari toko aplikasi mobile disaring dan dianalisis. Pendekatan machine learning digunakan untuk mengelompokkan ulasan pengguna. Analisis menunjukkan bahwa masalah pelanggan terbagi menjadi empat tema utama: tantangan spesifik, keamanan dan privasi, kesalahpahaman, dan masalah kepercayaan. Proses Software Process Assessment juga dilakukan untuk memeriksa keadaan saat ini dari dompet kripto dalam hal keamanan, kegunaan, dan kekayaan fitur. Sekitar 21 platform dompet kripto dieksplorasi dan dinilai. Berdasarkan analisis tematik dan penilaian proses perangkat lunak, rekomendasi fitur diusulkan untuk mengatasi kekurangan ini dan meningkatkan kredibilitas dompet mata uang kripto mobile.

Kata Kunci: Crypto wallet; software process assessment, analisis tematik, pengalaman pengguna.

INTRODUCTION

A cryptocurrency (crypto) wallet is often defined as a software application allowing users to

store, manage, and transact crypto assets such as Bitcoin, Ethereum, etc. Crypto wallets establish a unique field as they combine features of password managers, banking applications, and the need for



anonymity [1]. A crypto wallet is considered the primary interface for interacting with the asset in the blockchain. Unlike traditional wallets holding physical currency, crypto wallets do not store crypto assets [2]. Instead, they provide the means to access and interact with the digital assets on blockchain networks. The modern-day crypto wallet allows users to connect to various blockchain networks and switch assets across the network [3].

Technically, a crypto wallet operates by keeping track of private keys used to access cryptocurrency addresses and execute transactions [4]. Based on internet accessibility, crypto wallets can be categorized as online (hot) and offline (cold) wallets. A cold wallet is considered the secure version of a hot wallet, as the wallet is not exposed to the online connection. However, hot wallets are more convenient as they connect directly to the blockchain network.

Developing a crypto wallet is tricky as the developer should understand and consider security, usability, and feature richness. Security is crucial to protect sensitive data (private key) and transaction authorizations (signing) in a crypto wallet [5]. Usability can ensure widespread crypto wallet adoption by designing a wallet that understands the needs of new and experienced users. Feature richness drives the crypto wallet beyond its essential functionalities, transforming it into a dynamic tool that enhances the user experience. Balancing these three elements is crucial for creating a wallet that is both secure and user-friendly.

Recent scholarly investigations reveal that user experience (UX) research in blockchain-related technologies, including cryptocurrency, lags behind the current advancements in blockchain [6]. The prevalence of financial losses attributed to user misconceptions about the functionalities of crypto wallets serves as substantial evidence to support this observation [7], [8]. In their study, Kromholz et al. conducted a survey focusing on UX within the Bitcoin network, revealing a widespread lack of user understanding about available features, particularly regarding security and privacy, which frequently compromises their anonymity.

This gap in understanding may stem from inadequate usability in desktop and mobile-based crypto wallets, especially in executing basic operations. Users often encounter instructions written in overly technical language, which is challenging to comprehend, and they lack clear guidance on troubleshooting steps and problem-solving methods.

Since trust is a fundamental motivator among crypto wallet users, these usability issues

have a direct and adverse effect on the perceived reliability of these wallets, leading to a disproportionately low usage rate despite high adoption figures [7], [9]. To address general and domain-specific challenges, future wallet designs should incorporate user interfaces that offer comprehensive, user-centered information and implement systems to mitigate financial losses [10], [11].

The urgency of having a crypto wallet is underscored by the imperative need for secure transaction confirmation and safeguarding private key addresses. While keeping security, the crypto wallet should provide an excellent experience for its users. In principle, improving the user experience of crypto wallets increases crypto adoption. Crypto wallet developers should consider the user's needs when developing the platform.

This research aims to deepen the understanding of user perceptions regarding crypto wallets, with the user's perception poised to become the main driver for the future of crypto wallet design. This research will employ two primary methods: a thematic analysis of user reviews on mobile application stores and a software process assessment of crypto wallets. A detailed examination of various crypto wallet features, usability, and security aspects will be conducted.

Through these methodologies, the research intends to provide a comprehensive overview of the current state of crypto wallets. Afterward, the future feature requirements of the crypto wallet will be proposed as the guideline for further development.

MATERIALS AND METHODS

Our research utilizes two approaches to garner comprehensive insights into the crypto wallet. The first approach involves data mining and analysis, leveraging advanced techniques to extract meaningful reviews from the application store. This process allows us to uncover correlations, identify potential challenges, and reveal valuable information that may not be apparent through traditional methods. Concurrently, we employ a software process assessment approach that examines the crypto wallet to evaluate its effectiveness and adherence to security, usability, and feature richness.

The synthesis of findings from these two approaches is presented in the results section, providing a cohesive overview of the data-driven insights derived from the analysis and the actionable recommendations from the software process assessment. This comprehensive synthesis offers a nuanced perspective on the interplay

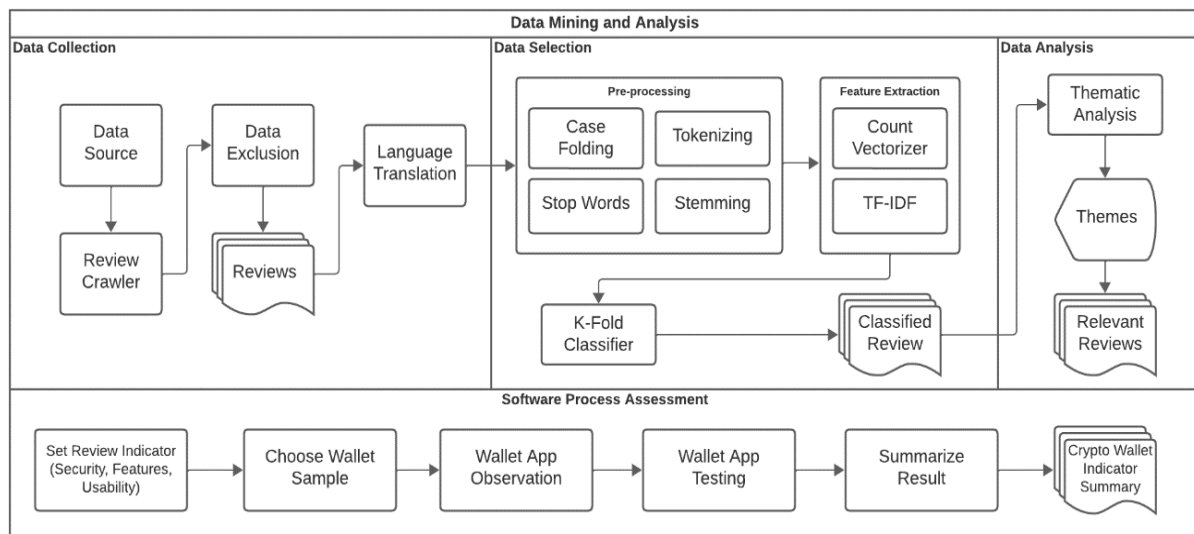


between quantitative data and qualitative process evaluations, enriching our understanding of the studied context and facilitating a well-rounded interpretation of the research outcomes.

Data Mining and Analysis

This research devised a methodical framework for examining the data essential for exploring users' preferences regarding cryptocurrency wallet features. Data acquisition was conducted through a web scraping technique, targeting user reviews on App Stores. After data

collection, a data cleansing phase was initiated, employing various pre-processing methods to distill the data to only that pertinent to the study. To ascertain the reliability and validity of the sampled dataset, the K-Fold validation technique was implemented, a crucial factor influencing the precision of the analysis. The final stage of the methodology involved the application of statistical thematic analysis. The primary objective of this phase was to discern prevalent trends, patterns, and potential challenges specific to mobile cryptocurrency wallets.



Source: (Research Results, 2024)

Figure 2. Research Methodology

Data Collection

Data Source - For this study, the top five mobile crypto wallets were chosen based on their popularity, user ratings, and the volume of reviews on both the Google Play Store and Apple App Store. The selected wallets were Blockchain Wallet, MetaMask, Trust, Coinbase, and Coinomi. User reviews were collected from the App Stores to compare user opinions across different platforms and operating systems.

Review Crawler - A custom-built crawler collected 35,806 reviews from the data source. The collected data includes the text of the reviews, their rating scores, the dates they were posted, and the versions of the applications at the time of the reviews.

Data Exclusion - Reviews comprising fewer than four words were omitted to maintain the integrity of the dataset. This exclusion criterion was applied assuming that such brief reviews may lack substantive content, potentially compromising the overall dataset's accuracy. After eliminating this

noisy data, the refined review collection retained approximately 27,934 entries.

Data Selection

This study employs a machine learning methodology to categorize review content. Initial processing techniques are applied to remove extraneous information and to homogenize the textual data. Subsequently, machine learning algorithms convert this processed text into numerical vectors, rendering it interpretable. The pre-processed dataset is then divided, with 80% allocated for training the model and 20% reserved for testing.

Pre-Processing - The raw text data was converted into a format suitable for analysis through several steps. First, all text was standardized to the same case (case folding) for consistency. Next, the text was divided into individual words (tokenizing), which helps eliminate stopwords or words that do not contribute to the analysis. Lastly, each word was



reduced to its root form (stemming) to enhance accuracy by minimizing variations in the text.

Feature Extraction - Four methods were employed to analyze the extensive user reviews of mobile crypto wallets. First, a count vectorizer was used to tally the frequency of specific words and phrases. The significance of each word and phrase was then assessed using the term frequency-inverse document frequency (TF-IDF) technique. Sentiment analysis was performed, assigning scores to reviews from -1 (extremely negative) to 1 (extremely positive) based on the occurrence of positive, negative, and neutral words. Finally, the data was divided into training and testing subsets to evaluate the accuracy of the feature extraction models.

Table 1. Classified reviews.

Classification	Review Text	Explanation
Related to Cryptocurrency	I was caught off guard by the fees. I deposited 100 USD but ended up with just about 75 in my account.	The high transaction fees caused a bit of dissatisfaction for the user.
UX in general	With the latest version 1.10.2, crashes are nearly eliminated, but the app still occasionally freezes on startup.	Focus on how the application behaves—nothing to do with cryptocurrency.
Irrelevant to UX	I'm hoping this will be my ticket to the moon!	Unrelated to the application or the cryptocurrency.

Source: (Research Results, 2024)

Training Set - Out of the 27,934 reviews, a subset of 1,000 reviews was randomly selected for categorization based on their relevance to user experience (UX). In this context, relevance is defined as the review's pertinence to specific features of mobile cryptocurrency wallets and insights derived from previous research. This categorization process sorts the reviews into three groups: those relevant to cryptocurrency, those about UX in general, and those deemed irrelevant to UX. Table 1 presents each review type's examples and explanations for their respective classifications.

Machine Learning Model - After finalizing the training dataset, we employed K-Fold validation to evaluate our machine learning model. Combining our pre-processing techniques, sentiment scoring, and random sampling resulted in an F1 score of 0.74 for reviews related to user experience (UX). The F1 score is a metric in machine learning used to assess a model's precision. A random binary classifier would have an Area Under the Receiver Operating Characteristic Curve (AUC-ROC) value of 0.5, while

a perfect classifier would score 1. Through 10-fold cross-validation, our classifier achieved an average AUC value of 0.84.

Data Analysis

Thematic Analysis - The analysis was selected for its proficiency in detecting and isolating data, facilitating the interpretation and formation of patterns [12]. In the subsequent phase, the reviews underwent a batch coding process. This process involved identifying themes within the coded data, each being defined and labeled to represent its essence accurately. As the analysis advanced, these themes were meticulously refined to ensure they precisely mirrored the data's content. This analytical process culminated in identifying four primary themes: domain-specific issues, security and privacy concerns, misconceptions, and trust aspects. The scope of the analysis was then concentrated on the most pertinent reviews for each theme, culminating in 5,466 reviews. Table 2 details the specific number of reviews selected for each theme from the different wallets.

Table 2. The count of classified and analyzed reviews for each wallet and platform

	Found Reviews	Classified Reviews	Analyzed Reviews
Metamask	1,794	1,498	613
Coinbase	2,360	2,581	1,401
Coinomi	1,692	850	405
Trust Wallet	16,130	4,016	1,884
BlockChain	3,958	2,761	1,163
Total	27,934	11,706	5,466

Source: (Research Results, 2024)

Software Process Assessment

Our software process assessment begins with setting review indicators that focus on security, feature richness, and usability. The following process is choosing samples of wallets, delving down into the features, and exploring the functionalities offered by the wallets to user needs and assessment standards. Usability considerations encompass examining user interfaces, intuitiveness, and overall user experience.

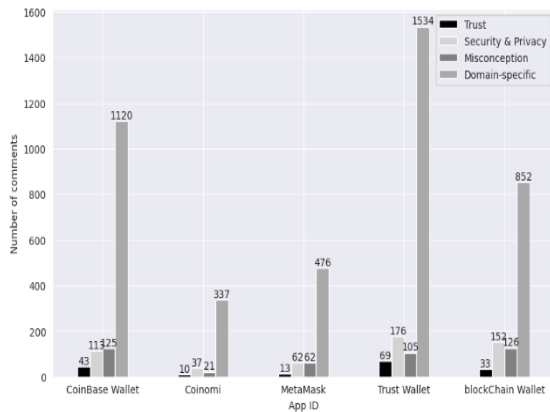
Wallet apps are observed in real-time usage scenarios to ensure a holistic assessment. Comprehensive testing is conducted by involving the download and installation of the selected wallet apps. This testing phase examines feature richness, ease of use, and any security issues that might impact user satisfaction. The results of these evaluations are then summarized to contribute valuable insights into the strengths and areas for improvement in non-custodial hot wallet applications.



RESULTS AND DISCUSSION

This section provides detailed outcomes from the research methodology using thematic analysis and software process assessment. The thematic analysis allowed for the distillation and categorization of critical themes and patterns embedded within the qualitative data, providing a view of intrinsic connections within the dataset. Integration with software process assessment helps gain insight into real case testing scenarios based on a wallet's usability, feature richness, and security. The results could help build the future architecture of a non-custodial hot crypto wallet.

Thematic Analysis Result



Source: (Research Results, 2024)

Figure 3. Identified Theme

The thematic analysis revealed four distinct themes, with domain-specific issues emerging as the most prevalent. This was followed by themes related to security and privacy, misconceptions, and trust.

Domain-specific - This theme focuses on issues unique to mobile crypto wallets.

Table 3. Findings in domain-specific themes

Review Text	Insight
Supports nearly all coins and allows multiple coins of the same wallet, a feature I've had issues with in other apps.	The reviewer prefers wallets that support multiple cryptocurrencies over those that do not.
The interface of [mobile wallet name] is poorly designed and easily targeted by phishing scams. My account was hacked, resulting in a loss of \$450!	The reviewer experienced financial loss due to the poorly designed user interface.

Source: (Research Results, 2024)

Our findings indicate a strong user preference for mobile wallets capable of storing multiple currencies. Wallets featuring this

functionality typically receive numerous positive reviews. Conversely, poor user interface design is a common critique in the reviews, noted to diminish the overall user experience and, in extreme instances, result in financial loss.

Security and Privacy - This was obtained from reviews addressing issues regarding mobile wallets' security and privacy.

Table 4. Findings in security and privacy theme

Review Text	Insight
The wallet feels very secure to me, thanks to features like password protection, biometrics, BIP39 passphrase, and the ability to combine these options.	The variety of security options offered by the wallet enhances users' sense of security
Despite never sharing my password, an unknown party accessed my wallet. Customer support responded with a bot, leaving me no choice but to delete my account.	Inadequate security measures and poor customer support can lead users to abandon the wallet.

Source: (Research Results, 2024)

The reviews highlight the necessity of multiple security measures, particularly emphasizing the importance of second-factor authentication. Additionally, the reviews underline the critical role of customer support in assisting users with issues related to sensitive personal information.

Misconception - This theme highlights the drawbacks resulting from user misunderstandings.

Table 5. Findings in misconception theme

Review Text	Insight
I've generally had no problems, except my balance seems really buggy and inaccurate after being transferred. Not sure why that happens.	The reviewer mentioned issues with the balance displayed after transactions, without understanding the cause.
The abundance of negative comments suggests that many people are unfamiliar with how crypto works. The balance takes time to sync with the blockchain.	The reviewer mentioned that the majority of users lack basic understanding of cryptocurrency.
Regarding the high transaction fees, they are not the wallet's fault; refer to this article [url to article about transaction fee]. It appears that no one is willing to take the time to understand how this technology functions.	

Source: (Research Results, 2024)

While certain issues arising from misconceptions could be attributed to developer shortcomings, our analysis suggests that the primary cause often lies in the users' limited understanding of how cryptocurrency functions.



Trust - This theme emerges from reviews that reflect users' confidence in the mobile crypto wallet.

Table 6. Findings in trust theme

Review Text	Insight
A wallet you can trust that gives you full control over your earnings	Users prefer having more control over their financial assets.
It's really frustrating to trust this wallet when there are so many scams customer support involving people pretending to be customer support!	The presence of proper support greatly impacts user trust.

Source: (Research Results, 2024)

Presently, certain mobile wallets exert a degree of indirect control over how customers administer their wallets. Our findings underscore the importance of providing users with maximal autonomy as a key factor in earning their trust. Additionally, the significance of robust customer support is reiterated within this theme.

Software Process Assessment Result

The foundational aspects of crypto wallets are anchored in four key features. Platform availability ensures accessibility across various devices and operating systems, promoting inclusivity and user adoption. Customizability, another vital factor, empowers users to personalize their wallet interfaces and functionalities, enhancing the overall user experience. On-ramp support is integral for facilitating the seamless conversion of traditional fiat currencies into cryptocurrencies, streamlining the entry process for newcomers. Incorporating a built-in crypto exchange within the wallet simplifies the trading experience. It consolidates various financial activities into a single, user-friendly platform. Figure 4 shows the curated leading crypto wallet primary feature. Only six crypto wallets have all complete basic features defined in the manual survey.

	MEW	Metamask	Zengo	Trust wallet	Ambire	Rainbow
Platforms	Web, Mobile, Browser	Web, Mobile	Mobile	Mobile	Web	Mobile
Customizable	Yes	Yes	Yes	Yes	Yes	Yes
On-ramp support	Yes	Yes	Yes	Yes	Yes	Yes
Crypto exchange	Yes	Yes	Yes	Yes	Yes	Yes

Source: (Research Results, 2024)

Figure 4. Leading crypto wallet basic features

User experience is a cornerstone for crypto wallet adoption. The survey revealed significant

elements contributing to a positive user experience. Diverse login methods, such as email authentication, ensure accessibility and strengthen security measures. Multi-protocol connection capability is essential for users managing diverse cryptocurrencies, enabling compatibility across different blockchain networks [13]. Integrating crypto name services through Ethereum Name Service (ENS) or an internal naming service enhances user-friendliness by replacing complex wallet addresses with human-readable names, reducing transaction friction. Figure 5 shows the curated leading crypto wallet with a great user experience. Only four crypto wallets meet all the user experience criteria on the manual survey.

	Argent	Ambire	Zerion	Coinpayments
Login with email	Yes	Yes	Yes	Yes
Multi-protocol Connection	Yes	Yes	Yes	Yes
Crypto Name Service	Yes	Yes	Yes	Yes

Source: (Research Results, 2024)

Figure 5. Leading crypto wallet user experience

Security is paramount in the crypto space, and our survey unveiled several vital features enhancing wallet security. Multi-Party Computation (MPC) [14] and multi-signature (multi-sig) [15] functionalities employ advanced cryptographic techniques to fortify the security posture of wallets. Maximal extractable value [16] safeguards users against potential financial losses, limiting withdrawal amounts to mitigate risks. Anonymity features prioritize user privacy, addressing concerns within the decentralized landscape. Furthermore, the integration of hardware wallets adds an extra layer of security by keeping private keys offline, reducing susceptibility to online attacks, and bolstering overall confidence in the security of digital assets. Figure 6 shows the curated leading crypto wallet with better security.

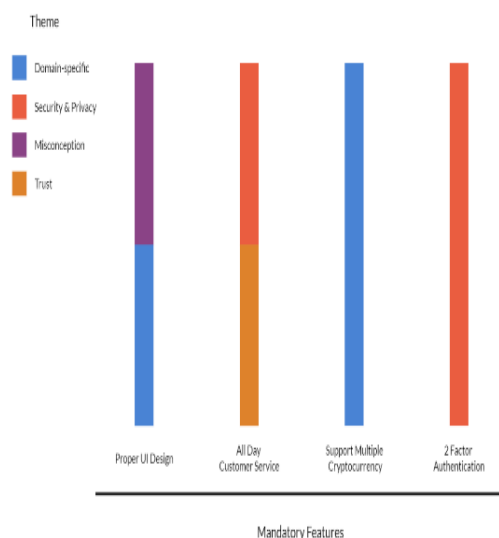
	Armory	Ambire	Coinomi
MPC	No	Yes	No
Multi-sig	Yes	No	No
Hardware Integration	Yes	Yes	Yes
Anonymity	Yes	No	Yes
MEV (Maximal Extractable Value)	No	Yes	Yes

Source: (Research Results, 2024)

Figure 6. Leading crypto wallet security

Mandatory Features Recommended for Future Design

Based on insights derived from the thematic analysis, the incorporation of various features is suggested. Anticipated outcomes from implementing these features include a notable surge in positive reviews relative to negative ones for the application. This shift is expected to assist current and potential users in making informed decisions about adopting the mobile wallet.



Source: (Research Results, 2024)

Figure 7. The crypto wallet's required features

CONCLUSIONS

The data classification identified four themes: domain-specific, security and privacy, misconceptions, and trust. The thematic analysis indicates that several features should be included in future mobile crypto wallets. These features are a well-designed user interface, 24/7 customer support, multi-cryptocurrency support, and two-factor authentication. Since the domain-specific theme was the most frequently identified (see Figure 3), it suggests that a well-designed user interface and multi-cryptocurrency support are the most crucial features for future mobile crypto wallets. Additionally, the other two features mentioned in Figure 7 are highly recommended to enhance trust between users and developers, thereby increasing the wallet's credibility compared to competitors.

The software process assessment has provided valuable insights into the strengths and areas for improvement within the landscape of crypto wallet development. Examining security measures, features, and usability has illuminated the current state of non-custodial hot wallets and

laid the groundwork for enhancing overall effectiveness and user experience. The findings from our assessment underscore the importance of continuous improvement in crypto wallet usability and security while emphasizing user-centric features to ensure the long-term viability of crypto wallets. Future research could contribute to designing a crypto wallet architecture that pays attention to improving user experience while enhancing the digital financial ecosystem.

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