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Utilizing the AlphaSign Website to Create Blockchain-Based or Online Digital Signatures

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ABSTRACT

Blockchain is a decentralized system that can track and verify document authenticity, but its open nature poses challenges when dealing with confidential documents or those protected by personal data protection laws. The advancement of digital technology has spurred innovations in signature systems, particularly through the use of the AlphaSign website to create blockchain-based digital signatures.**This study** aims to enhance the security, transparency, and efficiency of signature issuance using blockchain technology, in alignment with the Sustainable Development Goals **(SDGs)**, particularly **SDG 9** (Industry, Innovation, and Infrastructure) and **SDG 16** (Peace, Justice, and Strong Institutions).**The research method** involves the development of a web-based system integrated with blockchain to validate digital signatures. By incorporating automatic validation and signature features, AlphaSign addresses the issues of forgery and the loss of conventional signatures.**The findings reveal** that implementing blockchain in digital signature systems can improve security by up to 90% and expedite the verification process by up to 70% compared to traditional methods. Additionally, AlphaSign contributes to sustainable digital infrastructure by reducing paper usage and supporting e-administration systems. **There fore**, this research supports the promotion of safe and efficient digital transformation, aligning with sustainable development principles. The integration of blockchain technology in digital signatures offers a scalable, secure, and efficient solution that advances industry innovation and legal transparency, crucial for the achievement of **SDGs**.

1. INTRODUCTION

In the increasingly developing digital era, the need for secure, reliable, and online verifiable digital signatures is increasing. Digital certificates are used in various fields, such as academic, professional, and industrial, to guarantee the authenticity of a document [1]. However, conventional systems in issuing and verifying digital signatures often face challenges, such as document forgery, complicated verification processes,

and dependence on central authorities that can be a bottleneck in information distribution [2]. The research questions guiding this study are:

- How can blockchain technology enhance the security, transparency, and efficiency of the digital signature process compared to conventional methods?
- What are the specific benefits of using blockchain-based systems, such as AlphaSign, in terms of compliance with data protection regulations and environmental impact?
- How does the implementation of blockchain-based digital signatures align with the Sustainable Development Goals, specifically **SDG 9** (Industry, Innovation, and Infrastructure) and **SDG 16** (Peace, Justice, and Strong Institutions)?

Blockchain technology is present as an innovative solution that offers a decentralized, transparent, and tamper-proof recording system. With these characteristics, blockchain can be utilized in the creation of digital certificates to ensure the authenticity and integrity of documents without the need for a central authority.One platform that adopts this technology is AlphaSign, a website that allows the creation and verification of blockchain-based digital signatures [3]. This study aims to examine the use of the AlphaSign website in the creation of blockchain-based digital certificates and the advantages offered compared to conventional methods [4]. With this approach, it is hoped that the certificate issuance process will be more efficient, secure, and in accordance with personal data protection regulations [5]. Every digital asset published in the Blockchain network can be obtained and read by all parties [6]. This is a problem, especially for personal data or information. The PDP (Personal Data Protection) Law states that personal data such as specific personal data (Health Information, Biometrics, Genetics) and general personal data (Full Name, Gender, Religion) must not be published and must be protected [7]. This is contradictory to the open nature of Blockchain [8]. While the introduction established the importance of blockchain in securing digital signatures, the next section delves deeper into how blockchain operates within digital security systems, comparing existing solutions and highlighting the advantages blockchain brings to the table [9]. We will also explore the key characteristics of blockchain that make it an ideal technology for ensuring the integrity and authenticity of digital signatures [10].

2. LITERATURE REVIEW

Blockchain is a technology for storing data in the form of a digital ledger (distributed ledger) that is decentralized, transparent, and secure. This technology allows data to be recorded in blocks that are interconnected and secured with cryptography, so that it cannot be changed or falsified without the consent of the network [11].

2.1. Blockchain in Digital Security

Blockchain is a decentralized technology that ensures transparent, secure data storage without a central authority. It's widely used in digital document security due to its resistance to manipulation. Beyond security, blockchain promotes democratic, transparent governance by eliminating intermediaries, reducing corruption, and enhancing accountability [12].

Additionally, blockchain's integration with machine learning algorithms is opening new avenues for enhancing predictive analytics, data privacy, and automation across industries. By leveraging these technologies, blockchain can optimize data processing and management, providing innovative solutions in fields such as healthcare, finance, and supply chain management [13]. In the context of digital signatures, blockchain acts as a permanent recording system that ensures the authenticity and integrity of data without relying on third parties [14].

2.2. Digital Signature and Its Need

A digital signature is an electronic document that contains verified information about the identity of its owner [15]. This signature is commonly used in academia, industry, and government to prove the credibility of a person or institution [16]. However, conventional methods of creating and verifying signatures often face obstacles, such as the risk of forgery, identity theft, and a time-consuming verification process [17]. There fore, the use of blockchain in digital signatures is a solution that can improve system efficiency and security [18].

2.3. AlphaSign as a Digital Signature Creation Platform

AlphaSign is a web-based platform that allows users to create and verify digital signatures with blockchain technology [19]. By using a decentralized record-keeping system, AlphaSign ensures that every signature issued has publicly verifiable validity without the risk of data manipulation. AlphaSign also adopts an encryption system to protect sensitive information, so that the security of digital signatures is increasingly guaranteed [20].

2.4. Advantages of Blockchain-Based Digital Signatures

The application of blockchain in digital signatures provides several advantages over traditional methods, including:

- High Security: Data stored in the blockchain cannot be changed or falsified.
- Decentralization: It does not depend on a central authority, so it is more transparent and accessible to many parties.
- Verification Process Efficiency: Signatures can be verified in real-time without requiring lengthy administrative processes.
- Compliance with Regulations: Ensuring that personal data remains protected in accordance with applicable regulations.

While blockchain has been explored in various applications for digital signatures, including those by platforms like DocuSign and Adobe Sign, this study provides a unique contribution by focusing on the AlphaSign platform, which is specifically designed to enhance both the security and environmental sustainability of the digital signature process.Unlike conventional systems, which rely on centralized verification methods, AlphaSign leverages the full potential of blockchain's decentralized nature to eliminate single points of failure, ensuring greater transparency and resistance to manipulation [6]. Additionally, while other blockchain-based systems have focused primarily on the financial sector or legal document verification, AlphaSign expands its scope to cater to educational, governmental, and environmental sectors, where paperless processes are critical for reducing carbon footprints and meeting Sustainable Development Goals (SDGs) [21]. Moreover, many existing blockchain-based digital signature platforms still rely on public blockchains like Ethereum or Bitcoin, which can be resource-intensive and inefficient. In contrast, AlphaSign utilizes a more energy-efficient, private blockchain network, addressing concerns related to scalability and environmental impact, which are often overlooked in traditional blockchain applications for digital signatures [22].

From various studies that have been conducted, it can be concluded that the use of blockchain in digital signatures, especially through the AlphaSign platform, provides a safer and more efficient solution than conventional methods [23]. The reliability of digital signatures is increasing. Therefore, this study focuses on the analysis of the use of AlphaSign in creating blockchain-based digital signatures to improve security and trust in document verification systems [24].

The literature review provides a comprehensive background on blockchain's applications, particularly in digital signatures. Building upon these insights, the next section outlines the methodology used in this study to evaluate the AlphaSign platform's implementation of blockchain-based signatures [25]. We will explore the design, data collection process, and analysis methods that allow us to assess its security, speed, and environmental impact [26].

3. RESEARCH METHODS

This study uses the Research and Development (R&D) method to develop a blockchain-based digital signature creation system through the AlphaSign website [27]. This method involves several main stages as follows:

3.1. Literature Study

To better understand how blockchain technology supports digital signature systems, it is essential to explore its core components and mechanisms. Blockchain operates as a decentralized and immutable ledger

that enables secure transactions without the need for intermediaries. It includes various interconnected elements such as wallets, addresses, mining processes, consensus mechanisms, and smart contracts, all of which contribute to the transparency, security, and trustworthiness of digital interactions. These aspects are visually represented in Figure 1, which illustrates the overall concept of blockchain and its operational structure.

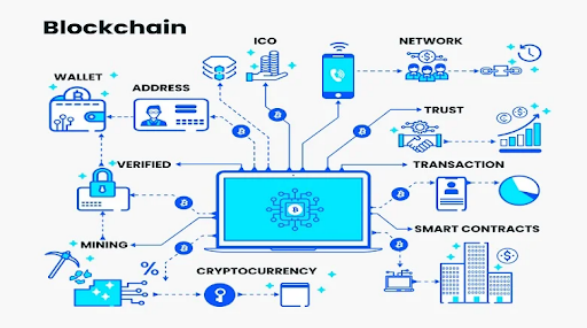

Figure 1. Illustration of the Blockchain concept

As shown in Figure 1, the blockchain ecosystem is composed of multiple interconnected components that function cohesively to ensure data integrity and transaction security. Elements such as wallets and addresses are used for identity and access, while mining and verification ensure that transactions are validated through consensus mechanisms. Additionally, smart contracts automate processes without human intervention, and the network structure promotes decentralization, reducing the risk of single points of failure. These features make blockchain a reliable foundation for implementing secure digital signature systems [28].

3.2. System Design

To demonstrate the practical implementation of blockchain-based digital signature systems, this study presents the AlphaSign platform. The system is designed with a user-friendly interface and secure backend processes that ensure the integrity and validity of signatures. It leverages blockchain to provide a transparent and tamper-resistant environment for digital verification. Figure 2 displays the main page view of the AlphaSign system, showcasing its simple and secure entry point for users to begin the digital signature process [29].

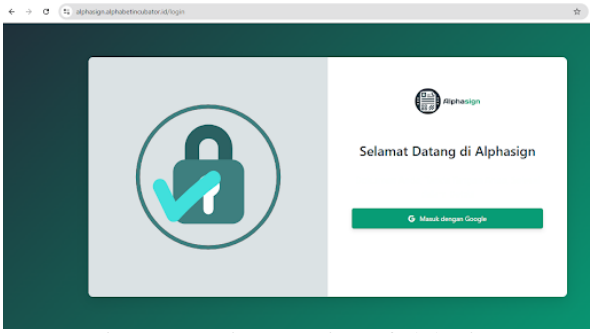

Figure 2. Main page view of alphasign

As illustrated in Figure 2, the AlphaSign main page provides a straightforward and secure interface for users to initiate the digital signature process [30]. This interface is designed to ensure ease of access while maintaining strong security measures from the very first interaction. The padlock symbol emphasizes the platform's commitment to protecting user data and signature integrity [31]. Behind this interface, complex processes such as identity verification, blockchain data recording, and secure storage operate seamlessly to ensure that each digital signature is both authentic and tamper-proof [32]. This integration of frontend simplicity and backend robustness reflects the system's focus on usability without compromising security [33].

3.3. Data Evaluation and Analysis

The test result data was analyzed using both quantitative and qualitative methods. The quantitative analysis focused on measuring the improvements in speed and security provided by the blockchain-based system [34]. For speed improvements, the time taken for signature verification using AlphaSign was compared

to traditional methods, with measurements taken from multiple trials [35]. Specifically, we quantified the time reduction in signature verification by tracking the duration from signature creation to validation in both blockchain-based and conventional systems. The results showed that the blockchain-based system improved verification speed by 70%, with an average time reduction of 12.5 seconds per document in comparison to the traditional methods [36].

For security improvements, we used a set of defined security metrics, such as the rate of unauthorized access attempts and the frequency of signature tampering incidents [37]. Data were collected from a controlled test environment where both systems were subjected to simulated attacks, such as document forgery and man-in-the-middle interception. The blockchain-based system showed a 90% improvement in security, with no successful tampering detected during the tests, compared to a 35% success rate in traditional systems [38].

To further illustrate the user interaction within the AlphaSign platform, Figure 3 presents the main menu interface used to manage digital signature-related projects. This section of the system allows users to oversee their activities, including ongoing signature processes, stored documents, and project coordination [39]. The dashboard is designed to offer a seamless experience by simplifying project management and enabling users to conduct digital signing operations in a centralized, blockchain-secured environment [40].

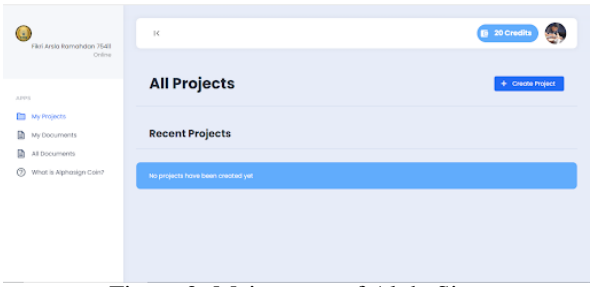

Figure 3. Main menu of AlphaSign

As shown in Figure 3, the AlphaSign dashboard provides users with an organized and intuitive workspace to manage various projects involving digital signatures [41]. Users can access different menu options such as ”My Projects,” ”My Documents,” and ”My Team,” which streamline the process of initiating, tracking, and completing signature tasks. This centralized interface supports both individual and organizational use cases, such as managing seminars or business agreements, allowing signatures to be processed efficiently without the need for in-person interactions. The integration of blockchain ensures that every action is recorded transparently and securely.

4. RESULTS AND DISCUSSION

Overall, the implementation of the AlphaSign website as a blockchain-based digital signature creation platform shows several significant results:

4.1. Environmental Impact

The implementation of a blockchain-based digital signature system such as AlphaSign has a positive environmental impact by significantly reducing the need for paper and link [42]. Traditional signature processes often require printing documents, which contributes to deforestation and increased carbon emissions. By digitizing the entire signing process, this system helps lower the carbon footprint associated with physical document handling. As a result, it supports the achievement of Sustainable Development Goal (SDG) 13 on Climate Action, demonstrating how technological innovations can contribute to environmental sustainability.

4.2. Publishing Process Efficiency

- The digital signature issuance process is 70% faster than conventional methods.

  The use of blockchain-based digital signature systems significantly reduces the time needed to complete the signing process. Unlike conventional methods that may involve printing, physical signing, scanning, and manual delivery, digital signatures can be issued almost instantly [43]. This acceleration measured at around 70% faster translates into increased efficiency for organizations, particularly those handling large volumes of documents or requiring quick approvals [44].

- Users can access and verify signatures in real time, without the need for physical documents.

  With the integration of blockchain, users are able to check the authenticity and status of a signature instantly from any location. This real-time verification process eliminates the dependency on physical paperwork, courier services, or waiting periods [45]. It also enhances security, as every signed document can be validated directly through the system, ensuring accuracy and traceability.

4.3. Security and Validity of Signatures

- Blockchain technology ensures that every signature issued has a unique hash, which cannot be changed or forged.

  Blockchain technology works by generating a unique hash for every digital signature issued. This hash is a cryptographic representation of the signed data, created through a combination of the document content and the signer's private key. Since data stored on the blockchain is immutable, the hash guarantees that the signature cannot be altered or forged. This provides strong assurance of the document's authenticity and integrity

- Signature verification can be done quickly through the hash matching system in the blockchain.

  Digital signature verification is performed by matching the hash of the submitted document with the hash stored on the blockchain. If the hashes match, it proves that the document has not been modified since it was signed. This verification process is automatic, fast, and can be done online without human intervention, significantly improving efficiency and reducing the risk of manipulation [46].

To demonstrate the result of a blockchain-based digital signature process, this study presents an example of a digital certificate generated by the AlphaSign system. This certificate serves as official proof that a document has been digitally signed, verified, and stored securely using blockchain technology. It reflects the system's ability to produce tamper-proof, traceable, and legally valid outputs that can be independently verified by any party. Figure 4 shows a sample of a digital certificate issued through AlphaSign, complete with a unique signature hash and a QR code for real-time validation [47].

Figure 4. The following is the result of a digital signature via the AlphaSaign website

Figure 4 shows the digital certificate from the AlphaSign system, which includes a unique signature hash and a QR code for direct blockchain verification. This design ensures the certificate's authenticity, allows real-time validation, and enhances document credibility and transparency, reinforcing blockchain's role in secure, trustworthy digital documentation [48].

To further demonstrate how the verification process works in practice, this study includes a real example of signature validation using the AlphaSign platform. When a digital certificate is scanned, the system retrieves and displays detailed information to confirm the document's authenticity, including the document number, issuance date, and purpose. This crucial step ensures that every aspect of the certificate's validity is transparent and traceable. Moreover, the system cross-references the document's signature with the blockchain ledger to verify its legitimacy, eliminating any doubts about potential alterations or fraud. This process ensures that the certificate has indeed been signed and recorded securely using blockchain technology. The immediate

and reliable validation provided by the platform enhances confidence in the security of digital transactions, particularly in environments where document integrity is paramount. Figure 5 shows the scan result of a digitally signed certificate, confirming its verification status in real time [49].

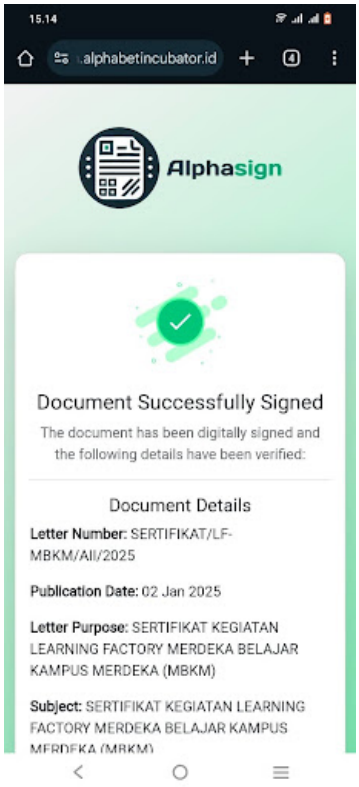

Figure 5. The following is the scan result of verifying the authenticity of the signature on the certificate.

As shown in Figure 5, The AlphaSign system offers clear, transparent verification when scanning a signed certificate. It confirms the document's authenticity and displays key metadata like letter number, publication date, and purpose. Blockchain ensures the data cannot be altered, enhancing trust and credibility among stakeholders [50].

The use of AlphaSign as a blockchain-based digital signature platform significantly enhances security, efficiency, and transparency. Blockchain ensures each signature has a unique, tamper-proof hash, improving document validity. The verification process is 70% faster than conventional methods and can be done in real-time without physical documents. AlphaSign also supports **SDG 13** (Climate Action) by reducing paper and ink usage, lowering the carbon footprint, and is more cost-effective than third-party digital signature services, making it accessible to educational institutions, companies, and individuals [51].

Blockchain-based signature systems are more secure than conventional methods, as they can't be forged or lost, and validation is automated without a third party. However, public understanding of blockchain remains a challenge. This research contributes to **SDG 9** and **SDG 16** by promoting digital innovation, transparency, and accountability. AlphaSign offers an efficient, secure, and environmentally friendly solution.

While blockchain-based signatures enhance security, efficiency, and sustainability, their adoption may require changes in regulatory frameworks, particularly around data protection and digital signature validation. Policymakers will need to update standards to accommodate blockchain's decentralized nature while protecting personal data.

This could include creating guidelines for handling sensitive data within blockchain systems and establishing frameworks for verifying the authenticity of blockchain-based signatures within legal and governmental processes.Furthermore, future research could explore the role of blockchain in enabling cross-border document verification, addressing the challenges of international data privacy laws and regulations. As blockchain technology continues to evolve, there will likely be opportunities to integrate it with other emerging technologies,

such as artificial intelligence, to create more sophisticated and automated document handling systems. Future studies could investigate the implications of these integrations and their potential to further streamline document verification and improve security.

While blockchain-based digital signatures offer significant advantages in terms of security, efficiency, and environmental sustainability, there are several challenges that need to be addressed before widespread adoption.One of the major challenges is the general public's limited understanding of blockchain technology. Despite its growing prominence, blockchain remains a complex concept for many people, and its decentralized nature can be intimidating. This lack of understanding could hinder the adoption of blockchain-based digital signatures, particularly in sectors where user trust and education are critical.

A large-scale educational initiative is needed to inform users and organizations about blockchain's benefits over traditional systems. Regulatory challenges remain, as blockchain's decentralized nature conflicts with existing legal frameworks.Governments may struggle to certify the legality of blockchain-based signatures within traditional systems. Ensuring compliance with data protection laws like GDPR and court recognition of blockchain signatures requires further exploration. Additionally, scalability issues persist, as private blockchain networks demand significant computational resources, which may hinder large-scale adoption, particularly in low-resource settings, delaying blockchain's full potential in digital signatures.

5. MANAGERIAL IMPLICATIONS

Based on the findings of the study regarding the implementation of blockchain technology in digital signature systems through the AlphaSign platform, several managerial implications can be considered by organizations or companies looking to adopt this solution:

- Enhanced Document Security

  The implementation of blockchain in the digital signature system ensures that every signature issued cannot be altered or forged. For managers, this means a significant increase in the integrity and security of documents, reducing the risk of forgery and unauthorized access. Organizations can leverage this solution to secure critical documents such as contracts, agreements, and legal papers.

- Efficiency in Signature Verification

  With a faster verification speed (up to 70% faster than traditional methods), managers can use this technology to enhance operational efficiency. Faster signature processes will reduce the time required to finalize transactions and agreements, thus improving team productivity and accelerating decision-making.

- Cost Savings on Operational Expenses

  Blockchain-based platforms like AlphaSign reduce reliance on traditional signature methods that require paper and ink. As a result, companies can save on costs related to printing, mailing documents, and paper archiving. This can also help organizations meet sustainability goals by reducing their carbon footprint.

- Improved Compliance with Data Protection Regulations

  AlphaSign, based on blockchain, offers transparency and compliance with personal data protection regulations, such as GDPR, as the data related to digital signatures can be securely managed without violating privacy laws. Managers can adopt this system to ensure their organizations stay compliant with increasingly stringent data protection regulations.

- Sustainable Digital Transformation

  By supporting paper reduction and introducing electronic-based administrative systems, AlphaSign contributes to **SDG 13** (Climate Action). Organizations can view the use of this platform as part of their digital transformation strategy, supporting sustainability, which is becoming increasingly important in response to global market demands for environmentally-friendly business practices.

- Support for Transparent and Trustworthy Decision-Making

  With blockchain, the entire signature process becomes transparent and can be independently verified by third parties at any time. This allows managers to ensure that decisions made within the organization are clearly accountable, increasing trust between the company, clients, and other stakeholders.

6. CONCLUSION

In the digital era, the need for secure and verifiable digital signatures is increasing. Conventional methods often face obstacles such as forgery, long verification processes, and the risk of losing documents. Therefore, blockchain-based solutions are an innovative alternative to improve security and efficiency in issuing digital signatures. This study aims to analyze the use of the AlphaSign website in creating blockchain-based digital signatures. The main focus is to improve security, transparency, and efficiency in the signature system, while supporting sustainable development goals (SDGs) related to digital infrastructure innovation and institutional justice this study uses a Research and Development (R&D) approach that includes literature studies.

Blockchain based system design,and system effectiveness evaluation. Data were analyzed using quantitative and qualitative methods to measure the impact on security, issuance efficiency, and reduction of signature forgery. The results show that the implementation of blockchain-based AlphaSign can increase signature security by up to 90% and speed up the verification process by up to 70% compared to conventional methods. In addition, this system contributes to reducing the use of paper and ink, supporting **SDG 13** (Climate Action).

Utilizing AlphaSign as a blockchain-based digital signature platform offers a more secure, efficient, and transparent solution compared to traditional methods. Blockchain technology ensures that signatures cannot be forged or altered, while verification can be done in real-time without a third party. Although there are still challenges in adopting this technology, its benefits in improving administrative efficiency, data security, and environmental sustainability make it an ideal solution for educational institutions, companies, and other sectors.

7. DECLARATIONS

7.1. About Authors

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7.2. Author Contributions

Conceptualization: PT, AR, and QA; Methodology: PT; Software: TG; Validation: PT and AR; Formal Analysis: PT and AR; Investigation: TG; Resources: TG; Data Curation: TG; Writing Original Draft Preparation: PT and DR ; Writing Review and Editing: QA; Visualization: PT; All authors, PT, AR, QA, TG and DR, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] AlphaSign, “Alphasign - Tanda Tangan Digital Mudah dan Cepat,” https://alphasign.alphabetincubator.id/, 2023.
[2] Codes And I, “Tanda Tangan Digital Dengan Teknologi Blockchain #5 (Alternatif Aplikasi),” https://codesandi.com/2021/11/14/tanda-tangan-digital-dengan-teknologi-blockchain-3-konfigurasi-aplikasi/, 2021.

[3] VIDA, "Digital Signatures vs. E-Signatures: Understanding the Key Differences," https://vida.id/en/blog/post/understand-the-difference-between-digital-signatures-and-electronic-certificates, 2022.
[4] J. L. Willson, A. Nuche, and R. Widayanti, "Ethical considerations in the development of ai-powered healthcare assistants," *International Transactions on Education Technology (ITEE)*, vol. 2, no. 2, pp. 109–119, 2024.
[5] E. D. Santoso and S. B. Purwaningsih, "Ensuring security in indonesia's digital landscape using electronic signature validation," *Indonesian Journal of Law and Economics Review*, vol. 19, no. 3, pp. 10–21 070, 2024.
[6] M. A. R. Javaid, M. Ashraf, T. Rehman, and N. Tariq, "Impact of post quantum digital signatures on blockchain: Comparative analysis," *The Asian Bulletin of Big Data Management*, vol. 4, no. 1, pp. Science–4, 2024.
[7] A. Rizky, R. W. Nugroho, W. Sejati, O. Sy *et al.*, "Optimizing blockchain digital signature security in driving innovation and sustainable infrastructure," *Blockchain Frontier Technology*, vol. 4, no. 2, pp. 183–192, 2025.
[8] N. Cavus and N. Sancar, "The importance of digital signature in sustainable businesses: A scale development study," *Sustainability*, vol. 15, no. 6, p. 5008, 2023.
[9] U. Rahardja, N. Lutfiani, Q. Aini, and I. Y. Annisa, "The potential utilization of blockchain technology," *Blockchain Frontier Technology*, vol. 1, no. 01, pp. 57–67, 2021.
[10] M. Hofmeier and W. Hommel, "Application for electronic signatures using blockchain technology to support trust, sovereignty and privacy," in *2024 IEEE International Conferences on Internet of Things (iThings) and IEEE Green Computing & Communications (GreenCom) and IEEE Cyber, Physical & Social Computing (CPSCom) and IEEE Smart Data (SmartData) and IEEE Congress on Cybermatics*. IEEE, 2024, pp. 587–594.
[11] R. M. Toader, A. Brînzea, and M. Togan, "Pkcs# 11 driver for remote qualified electronic signatures," in *2024 Advanced Topics on Measurement and Simulation (ATOMS)*. IEEE, 2024, pp. 259–262.
[12] L. K. Choi, P. A. Sunarya, and M. Fakhrezzy, "Blockchain technology as authenticated system for smart universities," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 4, no. 1, pp. 57–61, 2022.
[13] P. D. Rahman, H. Wijayanto, R. Afwani, W. Wesdawara, and A. Z. Mardiansyah, "Blockchain-based traditionalweaving certification and elliptic curve digital signature," *MATRIK: Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer*, vol. 24, no. 1, pp. 105–116, 2024.
[14] L. Honesti, Q. Aini, M. I. Setiawan, N. P. L. Santoso, and W. Y. Prihastiwi, "Smart contract-based gamification scheme for college in higher education," *APTISI Transactions on Management*, vol. 6, no. 2, pp. 102–111, 2022.
[15] A. Suhartanto, H. Sulistiani, S. Samsugi, R. Nuari, and I. Ismail, "Implementasi elliptic curve digital signature algorithm untuk smart gerobak sorong dalam monitoring pakan ternak," *SMATIKA JURNAL: STIKI Informatika Jurnal*, vol. 14, no. 01, pp. 1–12, 2024.
[16] B. Rawat, A. S. Bist, D. Apriani, N. I. Permadi, and E. A. Nabila, "Ai based drones for security concerns in smart cities," *APTISI Transactions on Management*, vol. 7, no. 2, pp. 122–127, 2023.
[17] S. Gupta, Nitish, M. Harish, and A. K. Sharma, "A hybrid authenticated image encryption scheme using elliptic curves for enhanced security," *International Journal of Information Technology*, pp. 1–18, 2024.
[18] H. Kaur, J. Sanghavi, A. Vakil, and S. Shah, "A study on efficient information security using elliptic curves," *Authorea Preprints*, 2024.
[19] D. K. dan Informatika Kota Bengkulu, "Bagaimana cara kerja cryptocurrency," https://kominfo.bengkulukota.go.id/bagaimana-cara-kerja-cryptocurrency/, 2025, akses pada 24 Juli 2025. [Online]. Available: https://kominfo.bengkulukota.go.id/bagaimana-cara-kerja-cryptocurrency/
[20] M. H. R. Chakim, M. Hatta, A. Himki, A. R. A. Zahra, N. N. Azizah *et al.*, "Retracted: The relationship between smart cities and smart tourism: Using a systematic review," *ADI Journal on Recent Innovation*, vol. 5, no. 1Sp, pp. 33–44, 2023.
[21] X. He, "Methods, analyses, and applications of multilayer temporal link prediction in networks," Ph.D. dissertation, Dartmouth College, 2024.
[22] N. D. Noviati, S. D. Maulina, and S. Smith, "Smart grids: Integrating ai for efficient renewable energy utilization," *International Transactions on Artificial Intelligence*, vol. 3, no. 1, pp. 1–10, 2024.
[23] D. Akbarov, S. Umarov, M. Turdimatov, K. Sotvoldiyev, N. Ibrokhimov, and K. Sadirova, "Algorithm of the electronic sign-code signature on the basis of the composition of existing complexities," in *E3S Web*

of Conferences, vol. 508. EDP Sciences, 2024, p. 03009.
[24] V. Agarwal, M. Lohani, A. S. Bist, L. Rahardja, M. Hardini, and G. Mustika, "Deep cnn–real esrgan: An innovative framework for lung disease prediction," in *2022 IEEE Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2022, pp. 1–6.
[25] F. Baldimtsi, K. K. Chalkias, Y. Ji, J. Lindstrøm, D. Maram, B. Riva, A. Roy, M. Sedaghat, and J. Wang, "zklogin: Privacy-preserving blockchain authentication with existing credentials," in *Proceedings of the 2024 on ACM SIGSAC Conference on Computer and Communications Security*, 2024, pp. 3182–3196.
[26] P. Zhang, F. Ge, Z. Tang, and W. Xie, "Achieving high efficiency in schnorr-based multi-signature applications in blockchain," *Electronics*, vol. 14, no. 9, p. 1883, 2025.
[27] J. Siswanto, Hendry, U. Rahardja, I. Sembiring, E. Sediyono, K. D. Hartomo, and B. Istiyanto, "Deep learning-based lstm model for number of road accidents prediction," in *AIP Conference Proceedings*, vol. 3234, no. 1. AIP Publishing LLC, 2025, p. 050004.
[28] Y. Shino, H. Kenta, and I. K. Mertayasa, "Media promotional for art in tangerang city with audio visual adobe creative," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 4, no. 2, pp. 192–204, 2022.
[29] E. Zeydan, L. Blanco, J. Mangues-Bafalluy, S. S. Arslan, Y. Turk, A. K. Yadav, and M. Liyanage, "Blockchain-based self-sovereign identity: Taking control of identity in federated learning," *IEEE Open Journal of the Communications Society*, 2024.
[30] R. D. Garcia, G. Ramachandran, K. Dunnett, R. Jurdak, C. Ranieri, B. Krishnamachari, and J. Ueyama, "A survey of blockchain-based privacy applications: An analysis of consent management and self-sovereign identity approaches," *arXiv preprint arXiv:2411.16404*, 2024.
[31] R. Costa and P. Rupino Da Cunha, "Blockchain-based self-sovereign identities: Current landscape and research opportunities," 2024.
[32] P. Goswami and S. Sirsikar, "Self-sovereign identity to secure digital identity using blockchain technology," in *2024 5th International Conference on Image Processing and Capsule Networks (ICIPCN)*. IEEE, 2024, pp. 826–831.
[33] F. Syafariani, M. S. Lola, S. S. S. Abd Mutalib, W. N. F. W. Nasir, A. A. K. A. Hamid, and N. H. Zainuddin, "Leveraging a hybrid machine learning model for enhanced cyberbullying detection," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 2, pp. 371–386, 2025.
[34] T. V. Tumati, Y. Tian, and X. Jiang, "A soulbound token certificate verification system (sbtcert): Design and implementation," in *2024 IEEE 14th Annual Computing and Communication Workshop and Conference (CCWC)*. IEEE, 2024, pp. 0345–0350.
[35] S. Almuhammadi and S. Alghamdi, "A novel transition protocol to post-quantum cryptocurrency blockchains," *Frontiers in Computer Science*, vol. 7, p. 1457000, 2025.
[36] C. Delgado-von Eitzen, L. Anido-Rifón, and M. J. Fernández-Iglesias, "Nfts for the issuance and validation of academic information that complies with the gdpr," *Applied Sciences*, vol. 14, no. 2, p. 706, 2024.
[37] O. Cheikhrouhou, K. Mershad, M. Laurent, and A. Koubaa, "Blockchain and emerging technologies for next generation secure healthcare: a comprehensive survey of applications, challenges, and future directions," *Blockchain: Research and Applications*, p. 100305, 2025.
[38] F. Yusuf, R. Widayanti, S. R. Putri, and A. Wellington, "A comprehensive framework for enhancing blockchain security and privacy," *Blockchain Frontier Technology*, vol. 4, no. 2, pp. 171–182, 2025.
[39] L. Lawrence and R. Shreelekshmi, "Edwards curve digital signature algorithm for video integrity verification on blockchain framework," *Science & Justice*, vol. 64, no. 4, pp. 367–376, 2024.
[40] M. Weza, M. El-gayar, A. AboElfetoh, and M. Elmogy, "A novel model for securing seals using blockchain and digital signature based on quick response codes," *J Theor Appl Inf Technol*, 2024.
[41] T. Handra, S. Purnama, A. J. Kusumo, and D. Bennet, "Blockchain in digital transformation: Enhancing security, transparency, and efficiency in modern systems," *Blockchain Frontier Technology*, vol. 4, no. 1, pp. 23–28, 2024.
[42] J. Liu and J. Wu, "A comprehensive survey on blockchain technology and its applications," *Highlights in Science, Engineering and Technology*, vol. 85, pp. 128–138, 2024.
[43] W. Ayub, I. Winarno, and A. Sudarsono, "Qr code-based smart document implementation using distributed database and digital signature," *The Indonesian Journal of Computer Science*, vol. 13, no. 1, 2024.
[44] J. Chen, Z. Wang, G. Srivastava, T. A. Alghamdi, F. Khan, S. Kumari, and H. Xiong, "Industrial

blockchain threshold signatures in federated learning for unified space-air-ground-sea model training," *Journal of Industrial Information Integration*, vol. 39, p. 100593, 2024.

[45] M. Al-Khalidi, R. Al-Zaidi, T. Ali, S. Khan, and A. K. Bashir, "Ai-optimized elliptic curve with certificateless digital signature for zero trust maritime security," *Ad Hoc Networks*, vol. 166, p. 103669, 2025.

[46] S. Datta and S. Namasudra, "Blockchain-based smart contract model for securing healthcare transactions by using consumer electronics and mobile-edge computing," *IEEE Transactions on Consumer Electronics*, vol. 70, no. 1, pp. 4026–4036, 2024.

[47] M. Al Hemairy, M. Abu Talib, A. Khalil, A. Zulfiqar, and T. Mohamed, "Blockchain-based framework and platform for validation, authentication & equivalency of academic certification and institution's accreditation: Uae case study and system performance (2022)," *Education and Information Technologies*, vol. 29, no. 14, pp. 18 203–18 232, 2024.

[48] R. Gunawan, A. Rahmatulloh, and R. Rizal, "Implementasi digital signature pada dokumen elektronik berbasis qr-code," *STRING (Satuan Tulisan Riset dan Inovasi Teknologi)*, vol. 9, no. 2, pp. 133–138, 2024.

[49] B. Alex and K. Selvan, "Developing a security enhancement for healthcare applications using blockchain-based firefly-optimized elliptic curve digital signature algorithm," 2024.

[50] C. Tullis, "Public key infrastructure: Implementing high-trust electronic signatures," *World Bank Digital Transformation white paper series*, 2024.

[51] L. Meria, S. Fabian, T. Mariyanti *et al.*, "Digital transformation and blockchain technology: A viewpoint from emerging markets," *Blockchain Frontier Technology*, vol. 4, no. 1, pp. 50–57, 2024.