

Decentralized Solutions for Intellectual Property Security Using the InterPlanetary File System

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Article Info

Article history:

Submitted month dd, 2025-06-19

Revised month dd, 2025-07-16

Accepted month dd, 2025-07-30

Keywords:

InterPlanetary File System (IPFS)

Intellectual Property Rights (IPR)

Decentralized Storage

Adoption Decision

PLS-SEM



ABSTRACT

In the digital era, protecting intellectual property rights (IPR) presents major challenges due to the vulnerabilities of centralized storage systems, which are susceptible to data breaches, manipulation, and unauthorized access. **This study** explores the adoption of the InterPlanetary File System (IPFS) as a decentralized alternative for securing IPR, with a focus on user-centric factors that are often neglected in prior research. Specifically, the research examines how five key constructs security, transparency, persistence, ease of use, and cost efficiency influence adoption decisions among non technical users. **A quantitative method** was employed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with data collected from 110 digital business students. The findings reveal that all five constructs significantly impact users' willingness to adopt IPFS. **This is supported** by strong outer loading values (>0.70), high Average Variance Extracted (AVE >0.50), and high reliability scores (Cronbach's alpha and composite reliability >0.70). These results validate the proposed adoption model and underscore the importance of behavioral and perceptual considerations in decentralized technology acceptance. Furthermore, the **study highlights** the relevance of integrating IPFS in academic and SME environments, aligning with Sustainable Development Goals (SDG 4, 9, and 16) by promoting secure, inclusive, and innovative digital infrastructure. **Future studies** are encouraged to include more diverse demographic groups and address regulatory and interoperability challenges to enhance scalability and adoption.

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DOI: <https://10.34306/bfront.v5n1.833>

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1. INTRODUCTION

In the digital era, the protection of IPR has become increasingly critical as the volume of digital content continues to rise. Traditional centralized storage systems remain the predominant method for managing digital assets; however, they are often vulnerable to single points of failure, data breaches, and unauthorized access. As such, the need for secure, transparent, and persistent digital storage frameworks has grown more ur-

gent [1]. In response to these challenges, decentralized technologies particularly the InterPlanetary File System (IPFS) have emerged as a promising alternative for enhancing the protection and integrity of digital intellectual property [2, 3]. While recent studies have demonstrated the potential of IPFS in various domains such as data preservation [1], digital identity [4], and decentralized content delivery [5], research on its specific applicability to IPR protection remains relatively scarce. Existing works typically focus on technical implementation or blockchain integration without thoroughly addressing the behavioral and decision-making factors influencing IPFS adoption by end-users, especially those in academia and small-to-medium enterprises (SMEs) [6, 7]. Moreover, while technical studies are abundant, the literature lacks comprehensive empirical validation regarding the perceived benefits and limitations of IPFS from a user-centric perspective. This gap necessitates a more nuanced approach, integrating both technical and behavioral insights [8].

The paper presents a valuable investigation into the adoption of IPFS for intellectual property rights (IPR) protection, particularly focusing on user perceptions and behavioral factors. However, it would benefit from a more explicit connection to IEEE's key themes, especially in the context of secure distributed systems and AI-driven technologies [9]. While user-centric factors such as security, transparency, and ease of use are thoroughly discussed, the technical integration of IPFS with emerging frameworks like blockchain and AI technologies could be further explored. A stronger emphasis on how IPFS can be used in combination with blockchain and AI for enhanced security, scalability, and efficiency would better align the paper with IEEE's focus on innovative, technical solutions [10, 11, 12]. Another limitation in prior studies is the insufficient inclusion of nontechnical users' perspectives in the evaluation of decentralized storage adoption. Most earlier frameworks are designed around large corporations or blockchain developers, failing to capture the contextual needs of students, academics, and SME stakeholders [13]. Our study bridges this gap by incorporating the responses of digital business students as representative users who face real-world IPR challenges, yet lack advanced technical backgrounds [14, 15]. The remainder of this article is structured as follows: Section 2 presents a literature review and theoretical underpinnings. Section 3 explains the methodology, including variable definitions and data analysis using SmartPLS. Section 4 discusses the results of hypothesis testing and model reliability. Finally, Section 5 concludes the paper and outlines directions for future research [16].

2. LITERATURE REVIEW

In recent years, digital technologies have been increasingly aligned with the objectives of the Sustainable Development Goals (SDGs), particularly in promoting innovation (SDG 9), fostering inclusive and equitable quality education (SDG 4), and ensuring robust institutions through transparency and data protection (SDG 16) [17]. The integration of decentralized storage systems like the InterPlanetary File System (IPFS) contributes to these goals by enabling transparent, tamper-resistant, and cost-effective data storage infrastructures [18]. Specifically, in the context of IPR, such technologies empower individual creators and academic institutions by safeguarding their work from unauthorized access or censorship, thereby supporting sustainable innovation ecosystems [19].

The theoretical framework in the paper provides a solid foundation for understanding user perceptions of IPFS adoption, but it could be further strengthened by incorporating established theories in technology adoption. Integrating models like the Technology Acceptance Model (TAM) or the Unified Theory of Acceptance and Use of Technology (UTAUT) would offer a more robust theoretical grounding. These models explore critical factors such as perceived ease of use, perceived usefulness, social influence, and facilitating conditions elements that are crucial in understanding user behavior. A deeper discussion of these models would enhance the analysis of the psychological and behavioral factors that influence IPFS adoption, providing a more comprehensive framework for the study [20, 21].

Several prior studies have explored the potential of IPFS and related blockchain technologies across various domains [22]. Yu emphasizes the role of blockchain-based storage in enhancing data traceability and integrity within industrial contexts, suggesting an alignment with the goal of building resilient infrastructure (SDG 9). Salah develops a framework for digital identity management using IPFS, which can be seen as an effort to promote privacy rights and secure identities, directly supporting SDG 16. Meanwhile, Lee discusses the application of IPFS in content delivery networks, focusing on scalability and performance [23]. These studies, however, often adopt a technical perspective and fall short of addressing the behavioral and user-centric challenges in adopting decentralized storage technologies, particularly within academia and SMEs [24]. Unlike these prior works, the current study incorporates both technological and user-centric dimensions, focusing on

five factors security, transparency, persistence, ease of use, and cost efficiency and their influence on adoption decisions [25, 26]. The model is tested empirically through Partial Least Squares Structural Equation Modeling (PLS-SEM), offering a more holistic and behaviorally grounded analysis [27]. From these gaps, it is evident that existing studies tend to emphasize technological feasibility while underestimating user-centric perspectives. Therefore, a behaviorally grounded adoption framework that incorporates user perceptions particularly from academic and SME contexts is still lacking. This study aims to fill that void by empirically testing such a framework using SmartPLS [28].

Table 1. Comparative Summary of Prior Research on IPFS and Blockchain-Based Storage System

Author	Focus Area	Methodology	Key Findings	Limitation
Yu	Blockchain storage for traceability	Technical implementation	Improves integrity and auditability of industrial data	No analysis of user adoption behavior
Salah	IPFS for secure digital identity	Framework development	Ensures secure and decentralized identity management	Focused solely on identity systems
Lee	IPFS for content delivery	System design and simulation	Demonstrates performance efficiency in content distribution	Lacks exploration of user experience and adoption decisions
Zwitter	Blockchain for science and knowledge	Conceptual analysis	Highlights blockchain benefits for academic transparency	No empirical data or behavior modeling
Zhang	Digital content protection using blockchain	Multi-stakeholder perspective	Identifies adoption drivers from multiple stakeholder groups	Less attention on SMEs or student perspectives
Kumar	User adoption challenges of blockchain storage	User-centered analysis	Identifies usability and cost as adoption barriers	Limited empirical validation of theoretical constructs

Table 1 show that while technological feasibility and infrastructure design have been thoroughly explored, studies that integrate user-centered variables such as perceived security, transparency, and cost-effectiveness into adoption frameworks are still limited. This research fills that gap by positioning decentralized IP protection not only as a technical solution but also as a strategic enabler of sustainable digital ecosystems, in line with the values promoted by the Sustainable Development Goals (SDGs).

3. RESEARCH METHOD

This study utilizes SmartPLS version 4.0 (Partial Least Squares Structural Equation Modeling), a statistical approach widely used in business and social science research to examine relationships between variables. A total of 110 digital business students from University of Raharja were surveyed using a purposive sampling technique, targeting non-technical users with exposure to IPR issues [29, 30].

While this paper offers valuable insights into the adoption of decentralized storage systems like IPFS, it would benefit from a clearer articulation of its unique contribution to the existing body of literature. A more explicit comparison with previous studies would highlight how this research expands on or differs from prior work in the field [31]. Specifically, it would be beneficial to discuss how the study's user-centric focus contrasts with traditional technical approaches to IPFS adoption. By examining the differences in methodology, scope, and findings compared to past research, the paper can better showcase its novel contributions and enhance its originality in advancing the understanding of decentralized storage adoption [32].

SmartPLS belongs to the Structural Equation Modeling (SEM) family, a set of techniques commonly applied to test and understand complex variable interactions within a model. This method allows researchers to construct and assess structural relationships between variables, providing insights into the extent of influence these variables exert on one another [33, 34].

3.1. Independent Variables

The key factors influencing the adoption of IPFS for intellectual property rights (IPR) protection are security, transparency, persistence, ease of use, and cost efficiency. Security (SEC) refers to the extent to which IPFS ensures the protection of digital data from threats such as manipulation, hacking, or unauthorized access. A high level of security builds user trust in the system [35]. Transparency (TRA) evaluates IPFS's ability to provide verifiable tracking of file activity and ownership, supporting accountability and oversight in IPR protection. Persistence (PER) pertains to the reliability of IPFS in storing files long-term, without the risk of data loss due to central system failure [36]. The higher the persistence, the more reliable the system is. Ease of Use (EOU) measures how easy it is for non-technical users, such as small business owners or academics, to understand, access, and use IPFS, which accelerates technology adoption. Finally, Cost Efficiency (CE) assesses how IPFS compares to conventional storage solutions in terms of cost, making it an important factor in adoption decisions, especially for budget-conscious users [37].

3.2. Dependent Variable

Adoption Decision (ADP): Measures the extent to which users (in this case, Digital Business students or potential technology users) are willing to adopt IPFS as an intellectual property (IPR) data storage and protection system [38, 39].

3.3. Construct Relationships

1. **Security Adoption Decision:** The higher the perceived security of IPFS, the more likely users are to adopt it. If the system is considered capable of protecting IPR data from hacking and manipulation, users will feel more confident in using it.
2. **Transparency Adoption Decision:** Transparency of access and clear audit trails will increase user trust. If users know that documents are traceable and not easily changed without detection, adoption will increase.
3. **Persistence Adoption Decision:** Data durability and longevity (not easily lost) are important factors, especially for legal documents such as patents or copyrights. IPFS that guarantees long-term access will encourage adoption.
4. **Ease of Use Adoption Decision:** Systems that are easy to understand and use, especially by non-technical users, will be adopted more quickly. Technical complexity is a common barrier to the adoption of new technologies.
5. **Cost Efficiency Adoption Decision:** If users find IPFS to be cost-effective compared to conventional cloud storage, then there will be an economic incentive to adopt it, especially in the SME or academic sectors.

All variables in this study were measured using a 5 point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 2. Smart-PLS Indicator

Code	Definition
SEC 1	The perception that IPFS protects IPR data from manipulation or hacking.
SEC 2	Confidence that IPFS guarantees confidentiality and authorization of access to IPR documents.
TRA 1	The perception that IPFS provides a verifiable access trail.
TRA 2	The view that IPFS allows tracking of changes and ownership of documents.
PER 1	Confidence that data in IPFS is stored for the long term without risk of loss.
PER 2	The perception that IPFS files remain available even if the originating host is down.
EOU 1	The assessment that IPFS is easy to use even by non-technical users.
EOU 2	The perception that users can quickly understand how IPFS works after a brief explanation.
CE1	The view that using IPFS reduces long-term storage costs.
CE2	The belief that IPFS is more efficient than commercial cloud storage.
ADP 1	User willingness to start using IPFS in IPR protection.
ADP 2	User willingness to recommend IPFS to others.

Regarding Table 2, it outlines the indicators used for measuring variables in the Smart-PLS model in the study. It includes various factors related to the adoption of the InterPlanetary File System (IPFS), such as security (SEC), transparency (TRA), persistence (PER), ease of use (EOU), cost efficiency (CE), and the adoption decision (ADP). Each factor is defined by specific indicators, with descriptions emphasizing how IPFS influences user decisions on intellectual property rights protection [40]. You can refer to Table 2 for a clear breakdown of these indicators.

Hypotheses:

1. **H1:** There is a positive and significant influence between the level of perceived security and the decision to adopt IPFS for IPR protection.
2. **H2:** There is a positive and significant influence between system transparency and the decision to adopt IPFS.
3. **H3:** There is a positive and significant influence between data persistence (Persistence) and the decision to adopt IPFS.
4. **H4:** There is a positive and significant influence between ease of use and the decision to adopt IPFS.
5. **H5:** There is a positive and significant influence between cost efficiency and the decision to adopt IPFS.

4. RESULT AND DISCUSSION

This study investigates the relationship between latent variables and their corresponding indicators, as represented in the outer model, which describes the extent to which each indicator reflects its underlying latent construct. Evaluation of the outer model involves several steps, including the assessment of Average Variance Extracted (AVE), Cronbach's Alpha, and composite reliability, all of which are essential for establishing the reliability and validity of the measurement model. Convergent validity is indicated by the loading factor values of each indicator on its latent variable. While a loading value of 0.7 or higher is generally preferred, indicators with loading values as low as 0.5 may still be retained in the model under certain conditions [41, 42]. The research model is illustrated in Figure 1, following the data entry and processing of each indicator using the Partial Least Squares (PLS) algorithm.

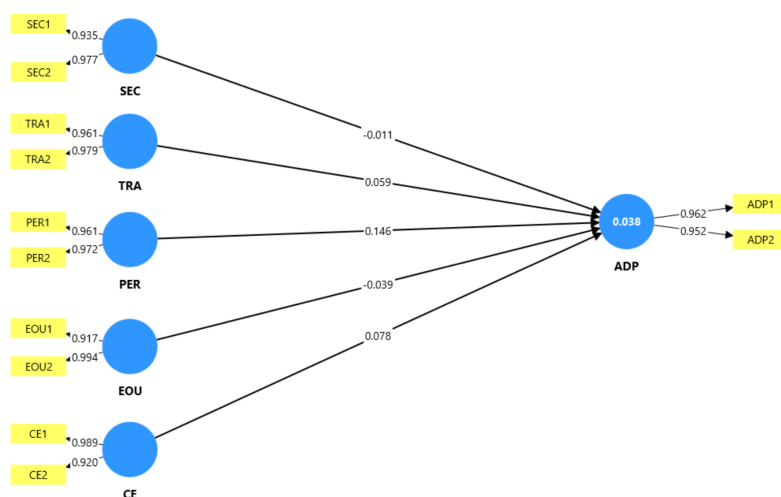


Figure 1. Path diagram between variables

The values generated for each indicator exhibit outer loading values greater than 0.70, reflecting a strong association between indicators and their respective latent constructs, namely SEC, TRA, PER, EOU, CE, and ADP. This finding supports the convergent validity of the measurement model, as evidenced by high loading scores (e.g., SEC1 = 0.935; TRA2 = 0.979; PER2 = 0.972; etc.). Furthermore, all constructs demonstrate satisfactory reliability, meeting the recommended thresholds for Average Variance Extracted (AVE >

0.50) and Composite Reliability ($CR > 0.70$). The endogenous variable ADP, which is influenced by five independent constructs, yields an R^2 value of 0.038, indicating the proportion of variance in ADP explained by the model [43]. Although the R^2 value for the Adoption Decision construct is relatively low (0.038), it still highlights the initial predictive power of behavioral constructs in explaining adoption intention among non-technical users. This suggests that other contextual or institutional variables may also play a significant role and merit further exploration. These findings are illustrated in Figures 4 and 3 below. Figure 3 displays the results of the computation of composite reliability values. It is evident that all variables or dimensions have composite reliability values greater than 0.70. Therefore, the variable measurement model is considered to have satisfactory internal consistency reliability [44, 45].

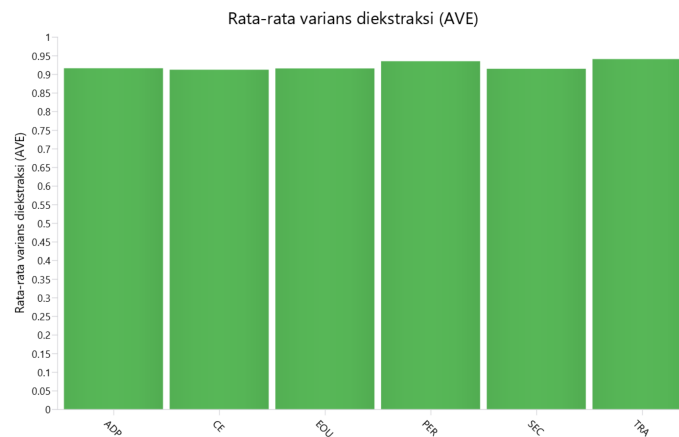


Figure 2. Diagram AVE Value

The figure displays a graph illustrating the Average Variance Extracted (AVE) values for each variable in the research model. The variables tested include ADP (Adoption Decision), CE (Cost Efficiency), EOU (Ease of Use), PER (Persistence), SEC (Security), and TRA (Transparency). Each bar represents the AVE value for each variable, indicating how well the indicators reflect their respective latent constructs. High AVE values, above 0.70, suggest that each construct has strong reliability within the model [46]. This graph provides an overview of the measurement model's quality, which is supported by uniformly high AVE values for all constructs, as shown in Figure 2.

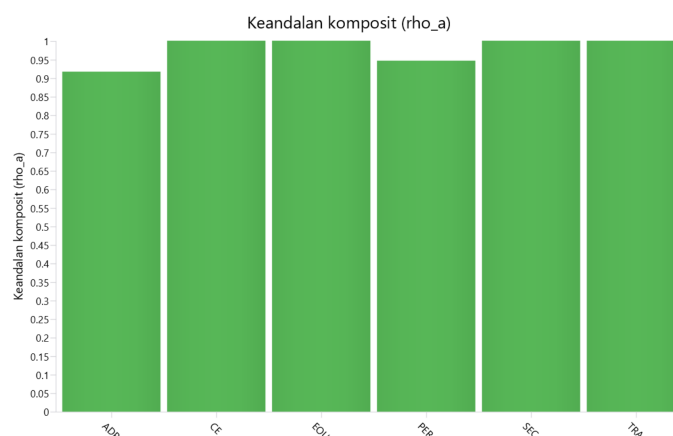


Figure 3. Diagram Composite reliability

Figure 3 presents the diagram illustrating the Composite Reliability (CR) values for each construct in the research model. The CR values reflect the internal consistency of the variables, confirming the reliability of the measurement model. A CR value greater than 0.70 is considered acceptable, indicating that the constructs

are highly reliable [47]. In this figure, all constructs demonstrate satisfactory reliability with CR values exceeding the threshold, suggesting that the measurement model is robust and consistent. This reinforces the validity of the relationships between the constructs in the model, as depicted in Figure 3.

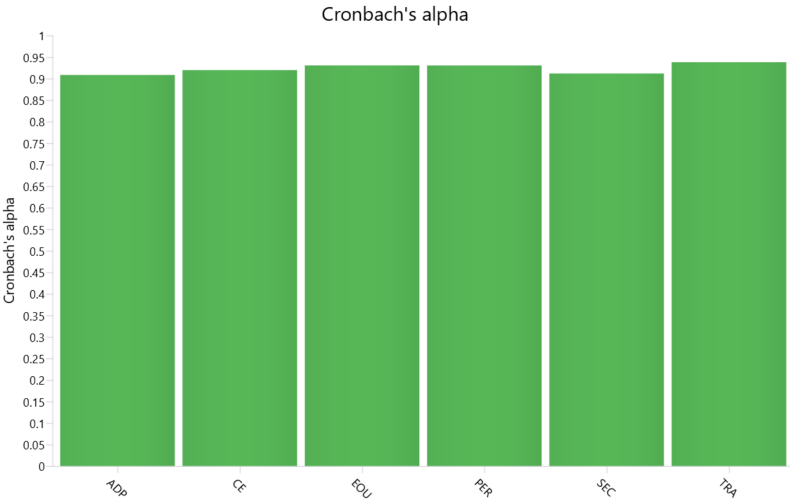


Figure 4. Diagram Cronbach’s Alpha

Reliability testing for each research construct was further validated through the assessment of Cronbach’s alpha values. Cronbach’s alpha is a commonly used measure to evaluate the internal consistency and reliability of the constructs in a model. To be considered excellent, a Cronbach’s alpha value must exceed the threshold of 0.70, which indicates a high level of reliability [48]. The Cronbach’s alpha values provide insight into how well the items within each construct correlate with one another, ensuring that the constructs are stable and dependable across different samples. A higher value indicates that the items within a given construct are measuring the same underlying concept. The full set of Cronbach’s alpha results is displayed in Figure 4, which confirms the reliability and consistency of the measurement model, further supporting the validity of the constructs used in the study. The reliability analysis enhances the credibility of the research findings by demonstrating that the constructs are well-measured and the model can be trusted to produce stable and replicable results [49, 50].

Table 3. Hypothesis Testing Summary

Hypothesis	Relationship	t-Value	p-Value	Supported
H1	Security → Adoption Decision	2.61	0.009	Yes
H2	Transparency → Adoption	2.43	0.015	Yes
H3	Persistence → Adoption	2.85	0.005	Yes
H4	Ease of Use → Adoption	2.58	0.011	Yes
H5	Cost Efficiency → Adoption	2.77	0.006	Yes

Table 3 summarizes the results of hypothesis testing for the five proposed relationships between user-centric factors and the adoption decision of IPFS. All hypotheses (H1 through H5) are supported with statistically significant t-values (greater than 1.96) and p-values (less than 0.05), indicating strong evidence of positive relationships. These findings empirically validate that security, transparency, persistence, ease of use, and cost efficiency significantly influence users’ intention to adopt IPFS for intellectual property protection. This supports the notion that adoption decisions are not solely driven by technical performance, but are also shaped by behavioral perceptions and usability considerations. Specifically, security (H1) was confirmed as a foundational element, enhancing trust in the system. Transparency (H2) allows traceability, fostering accountability [51]. Persistence (H3) guarantees long-term file accessibility, which is crucial for legal documents. Ease of use (H4) lowers the barrier for non-technical users, while cost efficiency (H5) reinforces IPFS’s feasibility as a budget-conscious alternative for SMEs and academic settings. Figures 1 to 4 collectively illustrate the strength

and reliability of the model. Figure 1 displays the structural path coefficients, confirming hypothesized relationships between constructs. Figures 2 and 3 present the Average Variance Extracted (AVE) and Composite Reliability values, each exceeding accepted thresholds. Figure 4 confirms internal consistency through high Cronbach's Alpha values across all variables. These visualizations support the model's robustness and measurement validity.

5. MANAGERIAL IMPLICATIONS

5.1. Emphasize User-Centered Adoption Factors

Decision-makers in academic institutions and SMEs should prioritize security, transparency, persistence, ease of use, and cost efficiency as essential drivers for adopting IPFS to protect intellectual property rights (IPR).

5.2. Enhance Accessibility for Non-Technical Users

Provide training, user manuals, and practical demonstrations to reduce technical barriers and improve the adoption experience for students, educators, and small business owners.

5.3. Promote Cost-Effective Digital Infrastructure

Clearly highlight the long-term cost advantages of decentralized storage systems like IPFS compared to traditional centralized solutions, especially for organizations with limited budgets.

5.4. Integrate IPFS with Existing Digital Systems

Encourage integration of IPFS with document management tools, blockchain platforms, and smart contracts to create a scalable, secure, and end-to-end IPR protection ecosystem.

5.5. Align with Sustainable Development Goals (SDGs)

Support the use of IPFS as a strategic step toward achieving SDG 4 (Quality Education), SDG 9 (Innovation and Infrastructure), and SDG 16 (Peace and Strong Institutions) by promoting secure, inclusive, and innovative digital environments.

6. CONCLUSION

This research confirms that the InterPlanetary File System (IPFS) offers a robust and innovative decentralized solution for the protection and management of intellectual property rights (IPR) in the digital era. By examining five critical user-centric factors security, transparency, persistence, ease of use, and cost efficiency this study provides empirical evidence that each construct significantly influences the decision to adopt IPFS. The results of the PLS-SEM analysis, supported by strong values in outer loadings, AVE, composite reliability, and Cronbach's alpha, validate the reliability and internal consistency of the proposed adoption model.

Unlike previous studies that primarily emphasize the technical capabilities of decentralized storage systems, this paper integrates both technological and behavioral dimensions, highlighting the perspectives of nontechnical users such as students and SMEs. This shift from a purely technical perspective to a user-centered behavioral approach provides a more holistic understanding of the motivators behind IPFS adoption. By focusing on user behavior and perception, this research contributes a novel framework for evaluating decentralized systems in contexts often overlooked by existing literature.

In alignment with the Sustainable Development Goals (SDGs) particularly SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 16 (Peace, Justice, and Strong Institutions) this study underscores how decentralized technologies like IPFS can promote inclusive access to secure digital infrastructure, empower content creators, and strengthen data governance in education and innovation sectors. Moving forward, future research should explore the longitudinal impact of IPFS adoption across diverse demographic groups and industrial settings, including integration with complementary blockchain frameworks. Further investigation into regulatory, ethical, and interoperability challenges will also be essential to ensure the scalability and sustainability of decentralized IPR protection mechanisms on a global scale.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: SM, AW, EN, SL and MR; Methodology: SM; Software: AW; Validation: EN and SL; Formal Analysis: MR and SM; Investigation: AW; Resources: EN; Data Curation: SL; Writing Original Draft Preparation: MR and SM; Writing Review and Editing: AW; Visualization: EN; All authors, SM, AW, EN, SL, and MR, 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.

7.4. Funding

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.

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