Investigating Technological and Organizational Leverages of Digital Learning Adoption in Halal MSMEs Using the TOE-TAM Framework and the PLS-SEM Approach

Popy Novita Pasaribu
Department of Management, Ibn Khaldun University, Bogor, Indonesia
popy.novita@uika-bogor.ac.id (corresponding author)

Muhamad Muslih
Department of Information Systems, Nusa Putra University, Sukabumi, Indonesia
muhamad.muslih@nusaputra.ac.id

Mashadi
Department of Management, Institut Bisnis dan Informatika Kesatuan, Bogor, Indonesia
mashadi@ibik.ac.id

Tika Kartika
Department of Sharia Economics, Ibn Khaldun University, Bogor, Indonesia
tikakartika@uika-bogor.ac.id

Hari Muharam
Department of Management, Pakuan University, Sukabumi, Indonesia
hari.muharam@unpak.ac.id

Hannisa Rahmaniar Hasnin
Departement of International Trade, Ibn Khaldun University, Bogor, Indonesia
hannisa@uika-bogor.ac.id

Received: 23 July 2025 | Revised: 10 September 2025, 23 September 2025, and 26 September 2025 | Accepted: 28 September 2025

 DOI: https://doi.org/10.48084/etasr.13606

ABSTRACT

This study investigates the adoption of cloud-based digital learning systems to empower halal Micro, Small, and Medium Enterprises (MSMEs) in Indonesia, which is still rarely explored. The objective was to evaluate the development and adoption of a cloud-based learning management system designed to empower halal-oriented MSMEs in Indonesia, called CSSL UMKM HalalPro. This study applies a system development approach using a structured waterfall model, and the adoption assessment uses Partial Least Squares Structural Equation Modeling (PLS-SEM) based on the Technology-Organization-Environment (TOE) framework and an integrated Technology Acceptance Model (TAM). The platform was developed to include a QR-verified presence, modular digital content, and real-time analytics tailored to the needs of MSMEs. Quantitative analysis was carried out on 179 MSMEs specializing in halal products with six latent constructs, including Adoption Intention (ADI), Digital Learning Behavior (DLB), Organizational Readiness (ORG), Perceived Ease of Use (PEZ), Perceived Usefulness (PRU), and Technology Readiness (TGR) with sub-latents 4, 4, 5, 4, 6, and 6, respectively. After eliminating indicators with low weights, the external evaluation showed that the model was highly reliable and had good construct validity. The internal model suggests that TGR impacts the perceived usefulness and ease of use of a product, which in turn influences the adoption intentions and digital learning behavior. ORG makes the product easier to use, but does not significantly influence perceived usefulness. This suggests that human and technological

factors have a greater impact on MSMEs than formal organizational competencies. The findings suggest that user-centered system design and TGR facilitate the adoption of digital technologies by MSMEs, thereby enhancing their capacity. This study uniquely integrates system development with adoption behavior analysis explicitly designed for halal-oriented MSMEs, a sector rarely addressed in digital learning research, and highlights that user-centered design and technology readiness are key to successful digital adoption in this context.

Keywords-CSSL UMKM halalpro; digital learning; halal economy; MSMEs; platform development

I. INTRODUCTION

Technical aspects (relative advantage and digital literacy) influence Indonesian MSMEs in using digital technology. In a study on the adoption of cloud-based accounting among 307 MSMEs [1], it was found that digital literacy and compatibility had a significant influence on perceived ease of use and utility of the software. In contrast, relative advantage only influenced perceived ease of use. These findings suggest that perceived ease of use is significantly influenced by digital literacy rather than solely by technological advantage. Furthermore, complexity serves as a barrier that reduces the willingness to embrace new technologies. The TAM model is relevant for explaining this phenomenon, particularly in the context of cloud-based learning, where users directly perceive the ease and benefits. The application of SEM-PLS in this study also demonstrated that further analysis allows for an in-depth understanding of the relationships between constructs.

In [2], the influence of managerial-level digital literacy on the digital transformation of MSMEs in Indonesia was highlighted. This study found that managers' digital literacy has a significant impact on the use of digital technology, which in turn drives digital transformation. In addition to manager demographics such as age and education, these micro-foundation variables strengthen the relationship between digital literacy and digital technology utilization. The results revealed that key individuals play a central role in the success of technology adoption at the tri-level organizational level. In other words, supporting technology readiness is insufficient without building the personal capabilities of users. Therefore, the operational level of users must be considered in designing a cloud-LMS.

Research based on the TOE framework has also evaluated the adoption of cloud computing by MSMEs in Indonesia. In [3], TOE-SEM-PLS was employed on 197 MSMEs, finding that relative advantage, organizational readiness, bandwagon effect, competitor pressure, and computer self-efficacy significantly influenced adoption. In contrast, complexity and top management support were found to have no significant influence. These results demonstrate the importance of organizational readiness and technology perception at the individual level. The absence of management support indicates a gap between formal policies and practical implementation. Furthermore, inaccuracies in top management aspects open opportunities to explore untapped environmental and cultural variables. This analysis is particularly relevant for encouraging the adoption of digital learning, with a focus on technical readiness and small organizations.

Research in the halal sector, particularly in relation to halal certification, also highlights the importance of literacy and entrepreneurial readiness. In [4, 5], self-declared literacy and business type were shown to significantly influence readiness and interest in halal certification among 200 MSMEs in Malang. These findings confirm that halal knowledge is closely related to the willingness to adopt new practices, including digitalization. Halal awareness is not only a religious aspect but also a strategic tool for marketing and reputation management. Therefore, halal literacy must be considered in the design of digital learning systems aimed at halal MSMEs, strengthening content relevance and increasing engagement.

In the broader context of technology adoption, the study in [6] applied the TOE-PLS-SEM model to AI adoption in e-commerce, highlighting the significant roles of perceived usefulness and perceived ease of use. Furthermore, knowledge absorption capacity serves as a mediator between adoption intention and outcomes. This study demonstrated that a framework that combines TOE and TAM effectively explained complex technology adoption. The combination of internal organizational capabilities with external technological factors yielded valuable insights. Furthermore, it was shown that PLS-SEM is an effective method for testing structural models that incorporate multiple elements. These ideas and concepts can be applied to the field of cloud-based digital learning, albeit in a different context.

The TOE framework identifies organizational and technological readiness as key determinants of innovation adoption [7]. TAM complements TOE by examining the perceptions of individual users, such as perceived usefulness and ease of use [8, 9]. Integrating TOE and TAM allows a comprehensive evaluation of both systemic and behavioral factors [10, 11]. Previous research has validated this model in areas such as supply chain management, GIS, and cloud systems [12-15], but few have examined its relevance in digital learning platforms tailored for SMEs, particularly within the halal industry.

In general, recent literature confirms that the adoption of digital technology in MSMEs is heavily influenced by digital literacy, compatibility, organizational readiness, perceived usefulness, and perceived ease of use, with environmental variables such as competitor pressure and the bandwagon effect also playing a role. However, aspects such as halal certification, QR presence, and modular content have not been empirically explored in the context of cloud-LMS for Indonesian halal MSMEs. Furthermore, previous research has focused more on the manufacturing or financial sectors, rather than halal-oriented education and training. This lack indicates a gap in the literature, as there has been no comprehensive study combining TOE-TAM and PLS-SEM to evaluate digital learning systems specifically designed to strengthen halal literacy and accelerate digitalization.

This study aimed to design and evaluate a cloud-based digital learning platform called CSSL UMKM HalalPro, specifically designed to empower halal MSMEs in Indonesia. The focus was on measuring the influence of technology readiness and organizational readiness on perceived ease of use and usefulness, as well as their impact on adoption intention and actual digital learning behavior, using the TOE-TAM framework analyzed with PLS-SEM. By incorporating technological, organizational, and individual constructs into a single model, this study is expected to generate both theoretical and practical insights. The system implementation is equipped with a QR-verified presence module, modular digital content, and real-time analytics according to user needs. This study aimed to provide user-centered and contextual design recommendations for halal MSMEs.

This study analyzes how Perceived Readiness (PRU), Perceived Ease of Use (PEZ), Technology Governance (TGR), and Organizational Support (ORG) influence Digital Learning Behavior (DLB) and adoption intention. A tested and ordered route model is presented for the Indonesian MSME landscape, which differs from previous studies that analyzed these components separately. With the use of rigorous statistical approaches, such as bootstrapping and multicollinearity evaluation, this work contributes to the field of empirical research by comprehensively integrating the TOE-TAM components and validating the model in a specific setting using PLS-SEM.

II. METHODOLOGY

A. System Development

With its waterfall-based development approach, CSSL UMKM HalalPro is well-suited for SMEs and environments with precise requirements. The project began with user requirements assessment, consulting with halal SMEs on learning modules, performance dashboards, and QR codes. The next step was to create a UML design that included system component diagrams, use case diagrams, and activity diagrams to ensure that the software structure met all functional requirements and processes. This implementation leverages a cutting-edge stack with a focus on modularity and reusable components, following Angular Minds' recommendations for a React-based LMS. Firebase handles the real-time backend, while ReactJS and Next.js handle the frontend. The system was subjected to black-box testing to ensure its stability and reliability, using the testing guidelines provided in [16] for e-learning systems. Thus, CSSL development was systematic, practical, and appropriate for the existing environment.

The waterfall method is supported by other studies that show that it is easily adaptable to develop LMSs and cloud-based learning systems in educational settings, especially when the requirements and constraints of the system are clearly defined. A distance learning recording system for elementary schools using the waterfall approach received a user satisfaction rating of 3.83 out of 5 for both functional correctness and user-friendly interface [17]. In [18], a cloud-based remote laboratory utilized an integrated system design and the Internet of Things to enhance the adoption of an engineering education platform and user engagement. The React-Firebase stack in CSSL enables modularity, rapid upgrades, and real-time analytics, as in [19], where a usability score of 83% was achieved with Flutter-Firebase. Thus, the CSSL development system not only adheres to technical best practices but also enhances functionality and user experience aspects based on global empirical evidence.

A voluntary and anonymous online survey collected all data except full name, address, identification number, and other sensitive data. Before participation, the respondents were informed of the purpose of the study, that their participation was optional, and that their responses would be used solely for academic purposes and provided in aggregate without prejudice. There was no harm to participants or personal or sensitive data, so this study did not require ethical approval. However, all data collection adhered to research ethics standards, including transparency, confidentiality, and respect for participant rights.

B. System Evaluation

The CSSL UMKM HalalPro system assessment was conducted using a combined approach of functionality testing and user satisfaction assessments, ensuring that the platform not only operates stably but also meets the needs of halal MSMEs. The testing phase included black-box testing for each module, as well as QR attendance, analytics dashboard, assignment upload, and multi-campus integration, to ensure system performance and reliability across various usage scenarios. Then a user satisfaction survey was conducted, adapting the Delone–McLean model to assess information quality, system quality, and the impact of use on user satisfaction. The responses indicated high satisfaction with both the system and information quality, which in turn positively influenced platform usage. This series of system evaluations verified that CSSL not only performs technically but also meets quality and functionality standards relevant to the halal MSME context.

In addition to functional measurements and user satisfaction, the system was theoretically evaluated by integrating PLS-SEM to ensure that its structural model conforms to the TOE-TAM framework. This aligns with the study in [8], in the education domain, which used PLS-SEM to evaluate the adoption of an LMS, and the review study in [20] that used SEM and TOE-TAM to examine LMS adoption factors in the agricultural education sector. The results showed that the technological context had a significant influence on perceived usefulness and ease of use. At the same time, organizational factors played a lesser role—a finding also evident in the CSSL evaluation. This evaluation approach allowed researchers not only to assess system performance quantitatively but also to analyze the relationships between variables in the adoption model and adjust it based on user feedback. Thus, this system evaluation stage not only provided technical validation but also provided a strong empirical foundation for further analysis on the level of adoption and digital learning behavior of halal MSME users.

A survey was conducted among MSME actors involved in the halal sector. Respondents participated through purposive sampling to select MSME respondents who were actively

involved in the halal industry, had experience or readiness to use digital technologies, and represented micro- to small-scale enterprises. The constructs were measured using previously validated indicators adapted for the SME digital learning context [10, 21, 22]. The analytical framework employed PLS-SEM, utilizing the Python language with the semopy library [23]. To assess the impact of CSSL UMKM HalalPro adoption, a structured questionnaire was developed based on validated constructs within the TOE-TAM framework. The instrument comprised six latent variables, each measured using multi-item indicators on a 5-point Likert scale. OGR consisted of five items adapted from [22], while TGR comprised six items, following the framework established in [11]. Davis's PRU and PEZ scales [21] have six and four items, respectively. In [9, 24], ADI and DLB were evaluated. Before distribution, the questionnaires were tested for clarity and reliability.

III. RESULTS AND DISCUSSION

A. Demography of MSME Respondents

The demographic composition of the respondents highlights the distinctive characteristics of halal MSMEs in Indonesia that are involved in the adoption of cloud-based digital learning (Figure 1). The majority of the respondents came from DKI Jakarta (35.75%) and Bogor (33.52%), reflecting the concentration of MSME activity in densely populated urban areas. The majority of respondents were female (75.4%), with most of them (89.39%) identifying themselves as business owners, indicating direct participation of business stakeholders in the technology adoption process. The largest age group was 41–50 years old (34.08%), followed by respondents aged 50 and above (25.14%), indicating that more mature business actors are also active in digital transformation. Respondents' education levels were relatively high, with over 90% being high school or college graduates. The majority earned less than IDR 10 million per month (81.56%) and had a monthly turnover of less than IDR 30 million (79.89%), indicating their classification as micro-enterprises. Although most businesses are new and small, with fewer than five employees, and under five years old, e-commerce adoption is quite significant, with 84.92% of respondents reporting an increase in revenue after adopting digital platforms.

B. Development of CSSL UMKM HalalPro System

The development of CSSL UMKM HalalPro is a strategic initiative that combines cross-campus collaboration and cloud technology to bridge the digital divide among halal MSMEs, as outlined in [25] through inter-campus documentation. The system was designed using the traditional waterfall methodology, starting with user needs analysis, UML (Use Case, Activity, and Component Diagrams) design, and implementation with ReactJS, Next.js, and Firebase for real-time data management. Core features, including location-verified QR attendance, a performance dashboard, assignment upload, learning monitoring, and multi-campus integration, were developed to meet the practical operational needs of MSMEs.

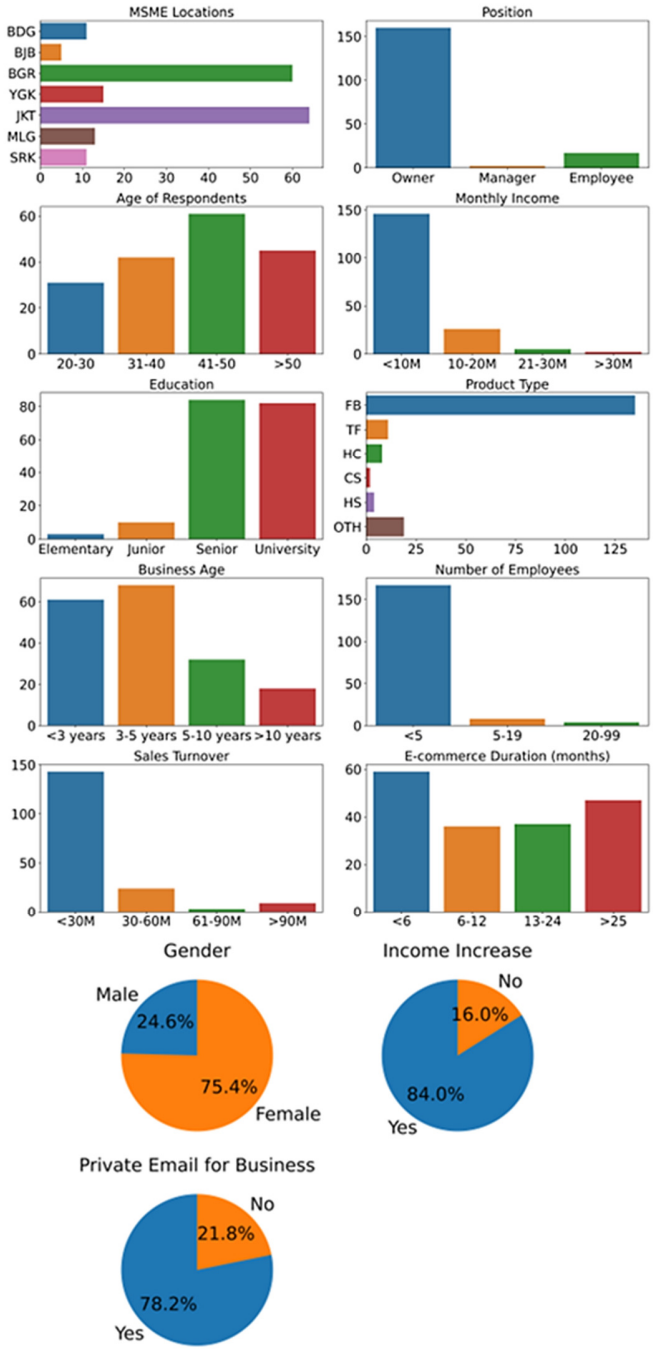

Fig. 1. Demography of MSME respondents.

Black-box testing demonstrated that all modules functioned stably and reliably, in accordance with the findings of [26] in the LMS evaluation that emphasized reliability during active use. The primary advantage is its ability to facilitate the sharing of academic resources across institutions, expanding access to standardized training for participants from diverse regions [27, 28]. Thus, CSSL serves not only as a digital tool but also as an instrument for empowering and enhancing digital capabilities for micro-enterprises with minimal infrastructure.

The development trend of the HalalPro UMKM CSSL is in line with the global trend of React-Firebase-based LMSs, which are now widely adopted in educational institutions and professional training. For example, an open-source LMS project utilizing React and Firebase [29] successfully created a functional dashboard for students, teachers, and administrators, demonstrating that this technology can support an interactive and integrated learning system. Furthermore, a study on the implementation of a Flutter-Firebase-based LMS achieved a usability score of 83%, proving that similar platforms can be relied upon on an educational institution scale [19]. These results also demonstrate the importance of real-time technologies, such as Firebase, for monitoring user activity and enabling adaptive content. Furthermore, a literature review on microlearning and social media showed that learning modules (similar to CSSL features) can significantly increase engagement and learning effectiveness [30]. This combination provides a strong theoretical and practical basis for designing features such as QR presence, modular content, and real-time analytics, as implemented in CSSL, opening opportunities for replication on a national scale in MSME digital empowerment programs.

C. Quantitative Analysis TOE-TAM Framework

The correlation analysis between latent constructs shows a strong and mutually supportive relationship in the TOE-TAM model (Figure 2). The highest correlation is observed between ADI and DLB at 0.92, indicating that adoption intention is strongly internalized into the actual user learning behavior. In addition, TGR has a high correlation with PRU (0.83), PEZ (0.79), and ORG (0.86), indicating that technology readiness not only impacts user perception but is also closely related to overall organizational readiness. The correlation between PRU and ADI (0.73) and between PRU and TGR (0.83) confirms that the perception of a system's usefulness is driven by technology readiness and directly influences the decision to adopt. Meanwhile, although PEZ has the lowest correlation with ADI (0.49) and DLB (0.50), its value remains in the moderate category, supporting the role of system ease in shaping intention and behavior. These results provide a strong basis for testing causal relationships in the inner model and demonstrate the alignment between constructs in the proposed conceptual framework.

These correlation findings align with [31], which examined the adoption of online learning systems and found that technology readiness had a strong correlation with perceived usefulness and organizational support, and indirectly influenced learning engagement. In [32], which examined mobile learning adoption among educators in Malaysia, it was also found that the highest correlation emerged between perceived usefulness and behavioral intention, followed by the correlation between intention and actual use, supporting the importance of perception in the adoption of digital-based systems. Both studies showed a pattern of relationships between variables similar to the findings in this study, particularly the dominance of TGR, PRU, and ADI in forming a strong and layered correlation. This confirms that in the context of digital learning, both in the general education sector and halal MSMEs, the relationship between technology perception and user intention remains a crucial element that is empirically consistent. The high correlation between ADI and DLB is also an important indicator that systems designed adaptively for users can encourage the transition from intention to real action.

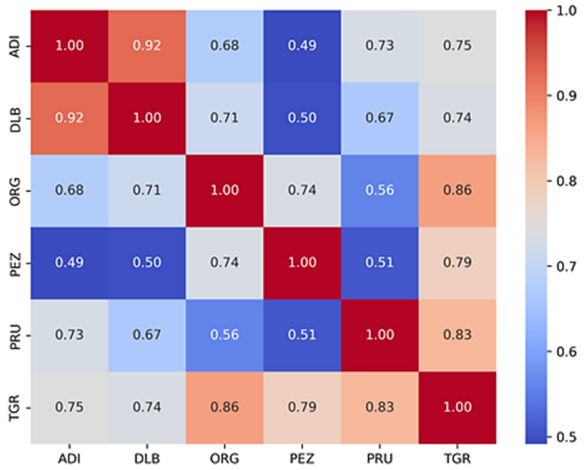

Fig. 2. Correlation of latent scores between construct variables.

The validity and reliability of the constructs in this study were generally acceptable, as shown in Table I. The Cronbach's alpha values for several constructs, such as PRU (0.879), PEZ (0.890), and ADI (0.929), exceeded the conventional threshold of 0.7, reflecting strong internal consistency among their indicators. However, the Composite Reliability (CR) values were relatively moderate, the highest being 0.570 for PEZ and 0.571 for ADI, suggesting that although the indicators consistently relate to their respective constructs, the magnitude of shared variance is not overly dominant. The AVE values ranged from 0.167 to 0.250, which fall below the commonly accepted threshold of 0.5, indicating limited convergent validity and suggesting that some constructs may only explain a smaller portion of the variance in their observed variables. This outcome suggests that, although internal consistency is intense, further refinement of the indicators may be necessary to improve the convergent validity. Despite the modest CR and AVE values, the constructs demonstrate acceptable reliability and offer a meaningful basis for further structural modeling.

Compared to previous studies, the validity and reliability results in this study tend to align with most of the constructs in earlier research. For example, in [3], which examined the adoption of cloud computing among MSMEs, several constructs achieved CR values of only 0.7, and the AVEs of several constructs fell within the marginal range of 0.45 to 0.6. Similarly, in [2], where TOE-TAM was integrated into AI adoption in manufacturing, it was found that the organizational readiness and ease of use constructs had Cronbach's alphas below 0.75. Compared to these studies, this study successfully maintained stability between indicators within the constructs, utilizing an indicator approach tailored to the context of halal MSMEs and a system design based on user needs. This reinforces the notion that the specific context and suitability of the system design to user characteristics can enhance internal

consistency and construct validity. Thus, this measurement approach can be said to be superior in capturing the dynamics of cloud-based digital learning adoption factors in halal MSME settings.

TABLE I. CONSTRUCT RELIABILITY AND VALIDITY

Construct	Cronbach's-α	CR	AVE
PRU	0.879	0.545	0.167
PEZ	0.890	0.570	0.250
TGR	0.684	0.505	0.167
ORG	0.776	0.554	0.200
DLB	0.760	0.569	0.250
ADI	0.929	0.571	0.250

CR: Composite Reliability, AVE: Average Variance Extracted

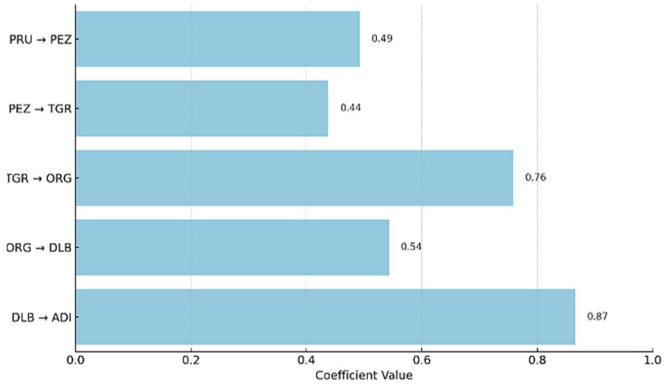

Fig. 3. Path coefficients from the SEM model.

The VIF analysis results for all variables, PRU, PEZ, TGR, ORG, and DLB, were 1.939, 1.825, 2.576, 2.224, and 2.612, respectively, showing that all variables have VIF values below 5. This indicates that there is no significant multicollinearity between the variables. In this model, PRU has a positive impact on PEZ, which in turn affects TGR, ORG, and DLB, the main predictors of ADI. The R^2 value indicates that this model can explain a significant percentage of the variance of each dependent variable. The largest ADI is 57.1%. Bootstrapping results (Table II) support this strategy with non-zero confidence intervals and low standard deviations. This underscores the importance of internal readiness and organizational support in accelerating the adoption of sustainable digital learning systems.

TABLE II. BOOTSTRAPPING RESULTS.

Path	Mean	Std Dev	CI Lower (95%)	CI Upper (95%)
PRU → PEZ	0.489	0.0834	0.3248	0.6409
PEZ → TGR	0.4396	0.0558	0.3272	0.5425
TGR → ORG	0.7548	0.0726	0.6023	0.8849
ORG → DLB	0.5403	0.0668	0.407	0.6693
DLB → ADI	0.868	0.0527	0.7582	0.9701

D. Inner Model

The results of the inner model analysis in Figure 4 illustrate the relationships between the constructs within the TOE-TAM framework, as tested using t-statistic values. The main findings indicate that TGR has a significant influence on PRU (t = 5.19) and PEZ (t = 4.06), indicating that technology readiness is an important driver in shaping user perceptions of the benefits and ease of use of the system. PRU and PEZ significantly influence ADI, with t-values of 5.94 and 2.33, respectively, thus strengthening the position of these two constructs as determinants of adoption intention. ADI has a strong relationship with DLB, with a t-value of 12.03, indicating that adoption intention indeed leads to actual user behavior. Interestingly, ORG actually showed an adverse effect on perceived usefulness (t = -2.00) and was insignificant on perceived ease of use (t = 1.79), indicating that organizational readiness is not a dominant factor in the context of halal MSMEs. This implies that adoption motivation is more determined by technological readiness and personal perceptions than by formal organizational structure.

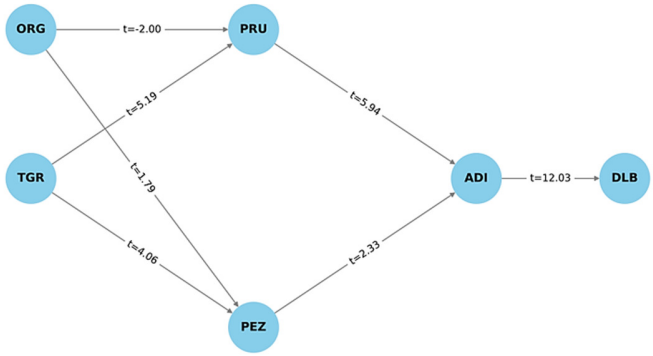

Fig. 4. CSSL UMKM HalalPro adoption using the TOE-TAM framework.

These findings align with and enrich the current literature in the domain of e-learning and digital learning adoption. For example, a study in Thailand [33] found that performance expectation and system quality significantly impacted LMS users' behavioral intentions, while formal organizational factors (such as institutional support) played a lesser role. A similar finding was observed in a study of the health sector in Somalia [34], which showed that direct technological and organizational factors (e.g., digital health technology readiness) were far more dominant than formal organizational variables in driving performance and behavior. Furthermore, a study on QRIS adaptation in Surabaya [35] revealed that perceived usefulness had a direct influence on intention to use, while perceived ease of use played only a mediating role, not a direct determinant. All three studies showed a pattern similar to that in this study: technological readiness and perceived usefulness were key factors, while organizational readiness had only a minimal or even negative contribution. This further emphasizes that a system design that strictly focuses on technical aspects and individual perceptions will be more effective in encouraging the adoption of digital learning in halal MSMEs.

E. Integrating the Two Approaches

By integrating a systems development perspective and empirical findings, this study demonstrates that user-centered design combined with adequate technological infrastructure is the key foundation for successful adoption [8]. The CSSL UMKM HalalPro operational model reflects how cross-institutional collaboration can be technically operationalized while simultaneously behaviorally aligning with MSMEs'

digital capabilities. The platform offers features such as QR code attendance, modular materials, and real-time data. It also utilizes adaptive learning, which allows the system to respond to users with varying levels of digital literacy. This method demonstrates that designing systems based on human preferences and experiences can increase people's adoption of new technologies and reduce resistance to them. Therefore, CSSL is not just a technology solution; it is also a digital empowerment tool that helps MSMEs accelerate their operations without harming the environment.

Complementing these findings, a study in the Bahraini SME sector [36] demonstrated that the perceived ease of use and the perceived usefulness of cloud computing solutions directly increase adoption and impact organizational performance. Another study in Indonesia [37] on cloud SCM adoption in SMEs found a similar pattern, with technology readiness, perceived ease of use, and perceived usefulness being the primary leverage, while organizational readiness even showed an adverse effect on perceived usefulness. These two results reinforce CSSL's user perceptions and technology design ideas. In support of the claim in [36] that a competent and user-friendly system is crucial, real-time feedback and well-chosen information will increase user engagement and involvement. CSSL offers an online learning platform to help halal SMEs become more competitive.

IV. CONCLUSIONS

This research arose from the need to provide relevant digital learning solutions for halal MSMEs in Indonesia, particularly within the framework of inclusive and user-centered technology adoption. MSMEs struggle to sustain their businesses due to the lack of easy access to adaptive and contextual learning tools. This study created and tested a cloud-based online learning platform called CSSL UMKM HalalPro, designed explicitly for halal MSMEs. The methodology employed included the creation of an integrated technology system while examining user adoption behavior using the TOE-TAM framework combined with PLS-SEM analysis.

The test results showed that technology readiness and user perceptions had a greater impact on system adoption than organizational considerations. This demonstrates the importance of building systems with users in mind and ensuring that they are user-friendly. The platform also successfully incorporates adaptive features, such as modular content, QR codes, and real-time progress monitoring, which have been shown to increase participation and learning effectiveness. In general, these findings provide a comprehensive understanding of how technology and user behavior can be effectively integrated to create a functional and widely accepted system. The main strength of this study lies in its comprehensive approach, which combines system development with user data-driven evaluation, providing a novel contribution to the development of digital platforms for halal MSMEs. Going forward, it is crucial to implement digital learning continuously and monitor its impact on MSME performance over time. This will help maximize the effectiveness of this established system.

ACKNOWLEDGMENT

The authors sincerely acknowledge the "Direktotat Jenderal Pendidikan Tinggi, Riset, Dan Teknologi" of the Republic of Indonesia for the research grant through the Scheme for the "Program Kolaborasi Penelitian Strategis (KATALIS) 2024". The authors also sincerely thank their collaborators in "Universitas Ibn Khaldun Bogor," "Institut Bisnis dan Informatika Kesatuan," Nusa Putra University, and "Universitas Pakuan," for fully uniting on this research consortium with the title "Superlatif Quadruple Helix G-A-B-C melalui CSSL untuk Mengatrol Transformasi Kemajuan dan Inklusifitas UMKM HalalPro".

REFERENCES

[1] A. M. Musyaffi *et al.*, "Exploring Technological Factors and Cloud Accounting Adoption in MSMEs: A Comprehensive TAM Framework," *International Review of Management and Marketing*, vol. 15, no. 1, pp. 283–292, Dec. 2024, https://doi.org/10.32479/irmm.17451.

[2] O. Destrian, "The influence of manager's digital literacy on SMEs' digital transformation in Indonesia: A micro-foundational context," *IEEE Transactions on Engineering Management*, pp. 1–14, 2025, https://doi.org/10.1109/TEM.2024.3467925.

[3] F. Aligarh, B. Sutopo, and W. Widarjo, "The antecedents of cloud computing adoption and its consequences for MSMEs' performance: A model based on the Technology-Organization-Environment (TOE) framework," *Cogent Business & Management*, vol. 10, no. 2, Dec. 2023, Art. no. 2220190, https://doi.org/10.1080/23311975.2023.2220190.

[4] H. Pratikto, Y. Agustina, and T. Mutiara, "Readiness and Interest in Halal Certification: Evidence of the Importance of Self-declare Literacy and Types of Business of Indonesian MSMEs," in *Proceedings of the 3rd International Conference on Halal Development (ICHaD 2022)*, May 2023, pp. 193–200, https://doi.org/10.2991/978-94-6463-188-3_20.

[5] M. Muslih, D. Gustian, . Somantri, and D. Hasman, "GIS Combined with Multivariate Analysis in Supporting Digitalization Supply Chain Management of Halal Products: The Case Study of MSMEs in West Java Indonesia," *Engineering, Technology & Applied Science Research*, vol. 15, no. 2, pp. 21152–21158, Apr. 2025, https://doi.org/10.48084/etasr.9991.

[6] B. Purwandari, B. Otmen, and L. Kumaralalita, "Adoption Factors of E-Marketplace and Instagram for Micro, Small, and Medium Enterprises (MSMEs) in Indonesia," in *Proceedings of the 2019 2nd International Conference on Data Science and Information Technology*, Seoul, Republic of Korea, Apr. 2019, pp. 111–116, https://doi.org/10.1145/3352411.3352453.

[7] D. Kalaitzi and N. Tsolakis, "Supply chain analytics adoption: Determinants and impacts on organisational performance and competitive advantage," *International Journal of Production Economics*, vol. 248, June 2022, Art. no. 108466, https://doi.org/10.1016/j.ijpe.2022.108466.

[8] R. Viswanathan and A. Telukdarie, "A systems dynamics approach to SME digitalization," *Procedia Computer Science*, vol. 180, pp. 816–824, 2021, https://doi.org/10.1016/j.procs.2021.01.331.

[9] V. Venkatesh and F. D. Davis, "A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies," *Management Science*, vol. 46, no. 2, pp. 186–204, Feb. 2000, https://doi.org/10.1287/mnsc.46.2.186.11926.

[10] H. O. Awa, O. U. Ojiabo, and B. C. Emecheta, "Integrating TAM, TPB and TOE frameworks and expanding their characteristic constructs for e-commerce adoption by SMEs," *Journal of Science & Technology Policy Management*, vol. 6, no. 1, pp. 76–94, Mar. 2015, https://doi.org/10.1108/JSTPM-04-2014-0012.

[11] T. Sulaiman, A. Mahomed, A. Rahman, and M. Hassan, "Understanding Antecedents of Learning Management System Usage among University Lecturers Using an Integrated TAM-TOE Model," *Sustainability*, vol. 15, no. 3, Jan. 2023, Art. no. 1885, https://doi.org/10.3390/su15031885.

[12] J. P. Shetty and R. Panda, "An overview of cloud computing in SMEs," *Journal of Global Entrepreneurship Research*, vol. 11, no. 1, pp. 175–188, Dec. 2021, https://doi.org/10.1007/s40497-021-00273-2.

[13] S. T. Siddiqui, S. Alam, Z. A. Khan, and A. Gupta, "Cloud-Based E-Learning: Using Cloud Computing Platform for an Effective E-Learning," in *Smart Innovations in Communication and Computational Sciences*, 2019, pp. 335–346, https://doi.org/10.1007/978-981-13-2414-7_31.

[14] M. S. Shahbaz, S. Sohu, F. Z. Khaskhelly, A. Bano, and M. A. Soomro, "A Novel Classification of Supply Chain Risks: A Review," *Engineering, Technology & Applied Science Research*, vol. 9, no. 3, pp. 4301–4305, June 2019, https://doi.org/10.48084/etasr.2781.

[15] Devianti, Fachruddin, E. Purwati, D. S. Thamren, and A. Sitorus, "Application of Geographic Information Systems and Sediment Routing Methods in Sediment Mapping in Krueng Jreu Sub-Watershed, Aceh Province, Indonesia," *International Journal of Sustainable Development and Planning*, vol. 16, no. 7, pp. 1253–1261, Nov. 2021, https://doi.org/10.18280/ijsdp.160706.

[16] A. Arcuri, M. Z. Iqbal, and L. Briand, "Black-Box System Testing of Real-Time Embedded Systems Using Random and Search-Based Testing," in *Testing Software and Systems*, Natal, Brazil, 2010, pp. 95–110, https://doi.org/10.1007/978-3-642-16573-3_8.

[17] K. Atthayuwat, K. Warunsin, K. Promjiraprawat, S. Pongyupinpanich, and P. Suwanloylong, "Applying the Waterfall Model to Develop the Student Learning Record and Assessment System for the Remote Public Primary School in Thailand.," *Journal of Positive School Psychology*, vol. 6, no. 3, 2022.

[18] H. A. Guerrero-Osuna *et al.*, "Developing a Cloud and IoT-Integrated Remote Laboratory to Enhance Education 4.0: An Approach for FPGA-Based Motor Control," *Applied Sciences*, vol. 14, no. 22, Nov. 2024, Art. no. 10115, https://doi.org/10.3390/app142210115.

[19] A. S. Laswi, A. Apriyanto, and A. Amruh A.M., "Implementation of Flutter-based Learning Management System (LMS) at Universitas Andi Djemma Palopo," *PENA TEKNIK: Jurnal Ilmiah Ilmu-Ilmu Teknik*, vol. 7, no. 1, Mar. 2022, https://doi.org/10.51557/pt_jiit.v7i1.1173.

[20] S. Demir and M. Uşak, "Analyzing the Implementation of PLS-SEM in Educational Technology Research: A Review of the Past 10 Years," *SAGE Open*, vol. 15, no. 2, Apr. 2025, Art. no. 21582440251345950, https://doi.org/10.1177/21582440251345950.

[21] F. D. Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly*, vol. 13, no. 3, pp. 319-340, Sept. 1989, https://doi.org/10.2307/249008.

[22] A. Kumar, R. K. Singh, and S. Swain, "Adoption of Technology Applications in Organized Retail Outlets in India:A TOE Model," *Global Business Review*, Feb. 2022, Art. no. 09721509211072382, https://doi.org/10.1177/09721509211072382.

[23] C. B. S. Tung, B. N. Dang, H. T. T. Nguyen, H. D. T. Lan, T. V. Tran, and L. B. Khac, "Enhancing Customer Experience in the Electronic Retail Industry in Vietnam: A Synergistic Approach of Structural Modeling and Strategic Management," in *Tech Fusion in Business and Society*, vol. 234, R. K. Hamdan, Ed. Springer Nature Switzerland, 2025, pp. 111–124.

[24] A. Habibi, M. Muhaimin, B. K. Danibao, Y. G. Wibowo, S. Wahyuni, and A. Octavia, "ChatGPT in higher education learning: Acceptance and use," *Computers and Education: Artificial Intelligence*, vol. 5, 2023, Art. no. 100190, https://doi.org/10.1016/j.caeai.2023.100190.

[25] P. Eosina, P. N. Pasaribu, A. Marlina, E. N. Himawan, A. Komariyah, and H. Kemora, "Preferences of MSME actors in Digital Marketing using AI-engine," presented at the 2nd Ibn Khaldun International Conference on Applied and Social Sciences (IICASS 2024), Nov. 2024, pp. 227–234, https://doi.org/10.2991/978-2-38476-299-6_17.

[26] K. Chi, Y. Yuan, and Q. Wang, "Trinity-Net: Gradient-Guided Swin Transformer-Based Remote Sensing Image Dehazing and Beyond," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 61, pp. 1–14, 2023, https://doi.org/10.1109/TGRS.2023.3285228.

[27] W. Tang, Y. Fu, P. Dong, W. Yang, B. Yang, and N. Xiong, "A MPTCP Scheduler Combined With Congestion Control for Short Flow Delivery in Signal Transmission," *IEEE Access*, vol. 7, pp. 116195–116206, 2019, https://doi.org/10.1109/ACCESS.2019.2933880.

[28] M. S. Nugraha and H. Rochimat, "Efektivitas Penerapan Sistem Informasi Manajemen Pendidikan Berbasis Cloud dalam Meningkatkan Efisiensi Administrasi Sekolah Menengah," *Jurnal Global Ilmiah*, vol. 2, no. 4, Jan. 2025, https://doi.org/10.55324/jgi.v2i4.175.

[29] D. O'Sullivan, F. Krewer, and G. Frankl, "Technology enhanced collaborative learning using a project-based learning management system," *International Journal of Technology Enhanced Learning*, vol. 9, no. 1, 2017, Art. no. 14, https://doi.org/10.1504/IJTEL.2017.084085.

[30] M. Denojean-Mairet, S. López-Pernas, F. J. Agbo, and M. Tedre, "A literature review on the integration of microlearning and social media," *Smart Learning Environments*, vol. 11, no. 1, Oct. 2024, Art. no. 46, https://doi.org/10.1186/s40561-024-00334-5.

[31] N. Ogbodoakum, A. F. M. Ayub, and N. Z. Abiddin, "The influence of individual and organizational factors on readiness to accept online learning among higher education lecturers in Nigeria," *Knowledge Management & E-Learning: An International Journal*, pp. 304–328, Sept. 2022, https://doi.org/10.34105/j.kmel.2022.14.017.

[32] J. L. Chong, A. Y. L. Chong, K. B. Ooi, and B. Lin, "An empirical analysis of the adoption of m-learning in Malaysia," *International Journal of Mobile Communications*, vol. 9, no. 1, 2011, Art. no. 1, https://doi.org/10.1504/IJMC.2011.037952.

[33] N. Thongsri, L. Shen, and Y. Bao, "Investigating factors affecting learner's perception toward online learning: evidence from ClassStart application in Thailand," *Behaviour & Information Technology*, vol. 38, no. 12, pp. 1243–1258, Dec. 2019, https://doi.org/10.1080/0144929X.2019.1581259.

[34] A. Jeilani and A. Hussein, "Impact of digital health technologies adoption on healthcare workers' performance and workload: perspective with DOI and TOE models," *BMC Health Services Research*, vol. 25, no. 1, Feb. 2025, Art. no. 271, https://doi.org/10.1186/s12913-025-12414-4.

[35] N. R. Firdausi and G. R. Antonio, "The Impact of the Technology Acceptance Model on the Use of QR Code Payment as a Digital Payment Method Among MSME Entepreneurs in the Culinary Tourism Center of Surabaya," *Journal of Entrepreneurship*, pp. 14–30, Feb. 2025, https://doi.org/10.56943/joe.v4i1.692.

[36] R. A. Abdalla, T. Ramayah, J. P. Sankar, L. A. Hidaytalla, and J. A. John, "Enhancing Efficiency: The Impact of Cloud Computing Adoption on Small and Medium Enterprises Performance," *Emerging Science Journal*, vol. 8, no. 6, pp. 2431–2448, Dec. 2024, https://doi.org/10.28991/ESJ-2024-08-06-017.

[37] P. N. Pasaribu, H. Kemora, and F. S. F. Kusumah, "Determinants of Cloud Computing of Supply Chain Management Adoption in SMES with Pilot Project," *Journal of Lifestyle and SDGs Review*, vol. 5, no. 4, Apr. 2025, Art. no. e5776, https://doi.org/10.47172/2965-730X.SDGsReview.v5.n04.pe05776.