International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8s, 2025
https://theaspd.com/index.php

Leveraging AI-Driven Chatbots For Sustainable Agricultural Advisory Services: Bridging SDG Innovation Gaps In Rural Malaysia

Chong Li Mei[1]
INTI International University

Wong Chee Hoo[2]
[a]Faculty of Business and Communications, INTI International University, Negeri Sembilan, Malaysia [b]Department of Economic Sciences, Wekerle Sandor Uzleti Foiskola, Budapest, Hungary [c]Faculty of Management, Shinawatra University, Pathum Thani, Thailand [d]International Institute of Management and Business, Minsk, Belarus.

Prakash Shaurya[3]
Visva-Bharati University, India

Kheyali Roy[4]
Assam Don Bosco University, India

Abstract: *The digital transformation of agricultural extension services is gaining momentum as governments and institutions seek to meet the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 9 (Industry, Innovation, and Infrastructure). In Malaysia, rural agricultural stakeholders often face limited access to timely, expert guidance due to infrastructure gaps, labour shortages, and communication inefficiencies. This study investigates the adoption potential of chatbot technology as an innovative, low-cost solution to enhance digital service delivery in the agricultural sector. Grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT), the research evaluates four key factors, Perceived Ease of Use, Perceived Usefulness, Social Influence, and Security Concerns, that influence behavioral intention to use chatbots among rural agri-entrepreneurs and extension officers. A quantitative cross-sectional survey was conducted with 124 respondents from key agricultural regions in Malaysia. Data were analyzed using SmartPLS 4, applying Partial Least Squares Structural Equation Modeling (PLS-SEM) to validate the measurement and structural models. The results revealed that Perceived Ease of Use and Perceived Usefulness had a statistically significant and positive influence on chatbot adoption, while Social Influence and Security Concerns showed weaker predictive power. These findings have direct implications for the design of digital agricultural interventions and policymaking, suggesting that usability and perceived value are critical to rural technology uptake. The study concludes with recommendations for embedding chatbots into Malaysia's national agri-extension platforms and highlights the need to enhance digital literacy in rural communities to achieve SDG-aligned agricultural resilience.*
Keywords*: Chatbot adoption, digital transformation, rural technology, SDG 2, digital literacy, perceived usefulness.*

INTRODUCTION

Agriculture continues to serve as a fundamental economic engine in Malaysia, contributing approximately 7.4% to national employment and 7.3% of GDP as of 2022 (Department of Statistics Malaysia, 2023). Most farmers in this sector are smallholders who depend on advice from government programs to help them farm, manage pests, deal with changes in the weather, and reach markets. Regardless of structural changes in agriculture, productivity is still limited by difficulties in sharing useful information and getting timely advice from experts. Services offered by agricultural extension have struggled with less budget, aging staff, and logistical problems getting to remote regions (Khairedine, 2023). As a result of these constraints, rural communities become more disconnected from the internet, which threatens the achievement of SDG 2 and creates additional inequalities among agricultural innovators in Malaysia. To overcome these gaps, digital technologies are increasingly being explored to modernize service delivery across the agricultural value chain. AI-powered chatbots seem

to be especially valuable in sharing information effectively and at a low cost. Chatbots respond to users using natural language, give instant answers to regular questions, and guide users to useful additional resources or support (Ismail et al., 2023). In agriculture, these platforms are able to deliver local weather updates, pest control advice, fertilizer suggestions, and news on subsidies. In India, chatbot functions have been incorporated into Kisan Suvidha, where the Ministry of Agriculture and Farmers Welfare India states that over 6 million people now use it to get timely and regionally translated advice (Ministry of Agriculture and Farmers Welfare India, 2022). AI platforms in China, like Pinduoduo's Smart Agriculture Competition, make use of chatbots to suggest crop advice based on the analysis of large amounts of data. They prove that chatbots are an effective way to help people in rural areas when knowledge is unevenly distributed. In Malaysia, government initiatives such as the National Agrofood Policy 2.0 (2021–2030) have explicitly called for digital transformation in agriculture, emphasizing smart farming, precision technology, and data-driven decision-making. Still, digital solutions in agriculture tend to benefit big corporations and city farms, while small farmers in Sabah, Sarawak, and Kelantan continue to meet challenges when adopting technology (Ministry of Agriculture and Food Security Malaysia, 2023). In a 2022 survey by the Malaysian Communications and Multimedia Commission, it was found that about 56% of those living in rural areas had consistent internet access, whereas over 90% in urban areas had this access (MCMC, 2022). This is a serious concern as over two-thirds of Malaysia's farms are run by individuals who are over 50 years old and may not be skilled enough to use technology-based solutions (Norazman et al., 2021). Since chatbots are available on WhatsApp and Telegram, they are an easy and affordable way for people to get into digital agriculture. Globally, the adoption of chatbots for public service delivery has accelerated, particularly in regions prioritizing digital infrastructure. In America, the Department of Agriculture has experimented with chatbot options to help people with farm loan questions, crop insurance matters, and disaster assistance by offering its help through AskUSDA. Response times have been cut by 70%, and more people are now using the agency's digital services, an increase of over 40% since the systems were first put into use (USDA, 2021). Agri-businesses are now making use of chatbot technology through the private sector. Bayer's Climate FieldView uses AI to assist farmers in getting the best results, which proves that people value and rely on farming automation (Bayer, 2023). Such stories prove that using AI-based communication tools in agriculture can help a lot when there are not enough people to go around. While chatbot technology offers considerable benefits, its uptake in rural Malaysian agriculture has been relatively slow. Key challenges include concerns over data privacy, limited trust in automated advice, and fear of misinformation, particularly among older and less formally educated farmers. According to a 2023 study by Furst et al., many rural users remain skeptical of chatbot systems, perceiving them as impersonal and error-prone compared to traditional in-person consultations. Additionally, the absence of content in local languages and the lack of multilingual assistance adds to the usability issues experienced in ethnically diverse rural communities (Cheong and Mohammed-Baksh, 2019). To be successful, agricultural chatbots must involve both new technology and opportunities for engagement among individuals, policy adoption, and the development of trust with users. Success in designing chatbots tailored to specific communities will depend on effective teamwork among government offices, startups, and community cooperatives. Given the dual pressures of climate change and food insecurity, the urgency to digitize rural agricultural services has never been greater. With more extreme weather, damaged soil, and pests appearing, it is important to get quick updates that simple pamphlets and occasional visits cannot offer (FAO, 2022). Chatbots driven by AI can take on these issues by mixing satellite information, information from users, and past trends to deliver action plans. For farmers in Malaysia, this ability is important since the sunniest areas along the Muda Development Authority corridor or East Malaysia, where crops may fail due to El Niño droughts and floods (Department of Agriculture Malaysia, 2023). When chatbot solutions are included in Malaysia's national agricultural extension plan, it can help strengthen the farming communities in rural areas, give them better access to knowledge, and contribute to achieving SDG 9's aims for fair infrastructure and responsible growth. This study aims to explore the adoption of chatbot technology as a tool for enhancing agricultural extension services in rural Malaysia. It focuses on identifying the main factors that influence the

willingness of rural farmers and stakeholders to engage with chatbot systems. The research examines how digital tools can support sustainable agricultural development and bridge rural information gaps. Ultimately, the study seeks to provide evidence-based insights to improve service delivery, drive innovation, and align agricultural support systems with national sustainability goals.

LITERATURE REVIEW

Theoretical Review

The Unified Theory of Acceptance and Use of Technology (UTAUT) acts as the main theoretical grounding for this study. UTAUT (see Figure 1) was developed by Venkatesh et al. (2003) and uses eight other technology acceptance models like the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and the Innovation Diffusion Theory. It works to reveal the intentions of users to use technology and why they actually use it by considering four main concepts: performance expectancy, effort expectancy, social influence, and facilitating conditions. The aspect of Performance Expectancy, which shows how useful technology is for a job, is commonly referred to as Perceived Usefulness in scientific studies. It explores the thoughts of people on chatbots and their potential to assist in crop management, information gathering, and making choices in agriculture. Historical studies show that people are more likely to adopt technology at work when they find it beneficial (Ghazali et al., 2018; Jaganathan et al., 2022). Due to the current study, this concept stands out as many Malaysian smallholders require simple and reliable options for advice after losing in-person services. Effort Expectancy, translated here as Perceived Ease of Use, captures the degree to which individuals believe that using a system requires minimal effort. For rural users with limited digital literacy, ease of navigation, intuitive commands, and voice or multilingual support can determine chatbot adoption (Cheong & Mohammed-Baksh, 2019). Studies in mobile commerce and e-government services have consistently shown that ease of use is a strong predictor of intention to adopt new technologies, particularly among older and less educated populations (Alam et al., 2022; Purnomo et al., 2020). Social Influence measures the extent to which individuals believe that people important to them think they should use a particular technology. In communal agricultural settings, influence from cooperative leaders, fellow farmers, and extension officers plays a critical role in shaping attitudes toward new tools (Alalwan et al., 2017). When users observe others in their network benefiting from chatbot use, such as receiving timely pest control tips, they are more likely to adopt the system themselves (Carlson et al., 2019). Therefore, the adoption of agricultural innovations in rural Malaysia relies heavily on getting peer and organizational approval. In this study, Security Concerns are the final construct, taking the place of the original UTAUT dimension called facilitating conditions. Even though infrastructure and support matter, the rural Malaysian environment demonstrates that trust and perceived safety with data is key in accepting technology. Many users are concerned about fake news, their private information being used, and dealing with a chatbot instead of a real person (Ischen et al., 2020). According to Pillai and Sivathanu (2020), people are less likely to use a digital system if they feel it is not safe or reliable, no matter how easy it is or how useful. UTAUT's flexibility makes it suitable for emerging technologies like chatbots and adaptable to rural environments with unique sociotechnical constraints. Its integration of both personal and environmental determinants of technology use provides a comprehensive framework for assessing digital tool adoption in agriculture (Kasilingam, 2020). For this study, the model is adapted to focus on Perceived Usefulness, Perceived Ease of Use, Social Influence, and Security Concerns, forming the conceptual base for the empirical investigation and hypothesis testing.

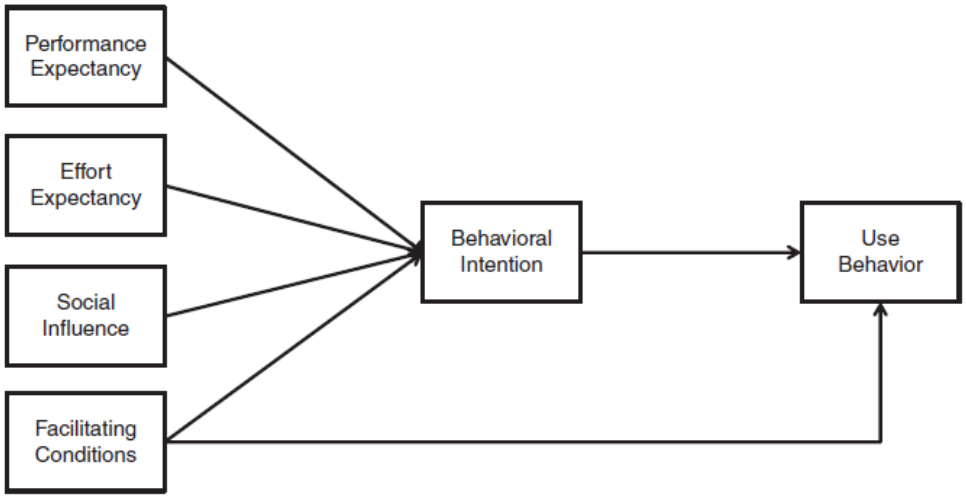

Figure 1: *Theoretical Framework (source: Suki & Suki, 2018)*

EMPIRICAL REVIEW

Usability and Navigation Simplicity in Rural Chatbot Systems

Among agricultural people in rural areas, usability is a key reason when it comes to adopting digital technology. Cheong and Mohammed-Baksh (2019) pointed out that, for farmers, tools that easily function on basic phones and do not need complicated navigation are more attractive. Making interfaces available in local languages, using voice, and adding images can help compensate for challenges faced by some users who do not know how to read or use written formats. In Malaysia, most farmers are older than 50, so chatbots should be designed in a simple way to help them understand basic operations (Norazman et al., 2021). Integrated tools on messaging platforms like WhatsApp have become more widely used since people find them both familiar and convenient (Ismail et al., 2023). Thus, chatbots should focus on simplicity, use regional languages, and design user flows that are straightforward so *everyone can benefit from them.*

Functional Value and Outcome Expectation

Perceived usefulness, which is how users evaluate the practical benefits of a system, significantly affects chatbot uptake in agricultural advisory contexts. Based on Jaganathan et al.'s study in 2022, Peninsular Malaysian farmers who relied on app advice for farming cycles were more satisfied and more likely to return to those apps. Because chatbots provide timely advice on weather, soil, or vote updates, many view them as reliable and valuable. By using Kisan Suvidha, which is a chatbot-powered platform, many Indian farmers now feel more confident with farming since they can receive real-time support and advice for better outcomes (Ministry of Agriculture and Farmers Welfare India, 2022). Thus, AI applications that visibly benefit farmers are more likely to be used by them. As a result, the chatbot should focus on agricultural topics that matter to users to help them stay interested in the long run.

Community Dynamics and Social Endorsement

Social influence helps shape digital behavior in rural areas; people often learn from others rather than getting formal guidance. Alalwan et al. (2017) pointed out that someone who sees a technology being recommended by peers, leaders, or authority figures in a collectivist society is more likely to use it. In Malaysia, most knowledge transfer and innovation diffusion happens through agricultural cooperatives and local community groups (Ghazali et al., 2018). When respected individuals like extension officers or farmers approve of a chatbot, more users start using it, which speeds up group adoption. Getting help from others makes farmers feel more confident in their digital choices, particularly when they lack trust in automated advice. As a result, training communities or using local ambassadors can increase active use of the system.

Digital Trust and Risk Perception

Rural areas with low computer education can lose trust in chatbot systems because of worries about misinformation, privacy, and system issues. Pillai and Sivathanu observed that if users doubt how their data gets used or are doubtful about automated responses, they tend not to use digital tools as much as they did before (Pillai and Sivathanu, 2020). As Ischen et al. (2020) found out, the rural population in developing countries commonly see chatbot responses as impersonal and filled with errors, especially if chatbots are not localized. If a chatbot is to be accepted in Malaysia, it should communicate using local phrases, idioms, and styles people are familiar with. Being open with data, getting feedback from the community, and having third-party approval can ease people's psychological worries. It is important for designers to include offline backups, human inputs, and verifiable sources to enhance trust in chatbot systems that provide advice.

Infrastructure and Access Gaps in Rural Technology Use

Although national efforts are focused on digital agriculture, having reliable internet and suitable devices is still preventing chatbots from reaching rural communities in Malaysia. A study by MCMC (2022) showed that just 56% of rural homes could get reliable internet, whereas more than 90% of those in cities had it. Not having enough reliable electricity and affordable smartphones creates more problems for the digital divide. According to Manaf et al. (2023), regardless of their openness to digital tools, a lack of suitable infrastructure makes farmers use classic farming methods. Lack of access to digital tools reduces both the beginning of chatbot use and the chance that it will be used in the future. Therefore, it becomes necessary for developers to focus on offline features, send-only text messages, and extremely lightweight apps that run without Internet connection to guarantee equal access to users.

Literacy Barriers and Interface Preferences

Technological tools often fail in rural areas due to poor alignment with users' language skills and cognitive preferences. Alam et al. (2022) observed that mobile apps designed for urban users often employ English-centric interfaces that alienate older and less-educated farmers. In a usability study among paddy farmers in Kedah, Samsudin et al. (2021) reported that icon-based and voice-assisted chatbots led to significantly higher rates of correct information recall compared to text-heavy systems. The success of chatbot interfaces thus hinges on their ability to cater to vernacular dialects and visual cognition patterns common in rural Malaysia. Visual cues such as crop icons, color-coded alerts, and spoken prompts can help bridge the gap between advanced AI technologies and traditional knowledge systems. Language inclusivity and low-literacy design features are non-negotiable for the widespread adoption of advisory chatbots.

Gaps in Longitudinal Adoption and Outcome Evaluation

Most existing research focuses on the intention to adopt chatbot technology but rarely assesses sustained engagement or impact on farming outcomes. Kasilingam (2020) criticized the overreliance on cross-sectional studies that provide snapshots of user behavior without capturing real-world usage patterns over time. There is limited empirical work in Malaysia that examines how chatbot usage influences farm productivity, cost savings, or environmental outcomes beyond the pilot phase. Moreover, few studies incorporate control groups to test whether observed benefits are directly attributable to chatbot use or external variables. To bridge these gaps, future research must employ longitudinal designs, real-time usage analytics, and comparative outcome evaluations. Such studies can inform policymakers and developers about the true value of chatbot systems in achieving SDG-aligned agricultural development.

Conceptual Framework

The conceptual framework for this study is developed based on empirical themes and theoretical grounding in the Unified Theory of Acceptance and Use of Technology (UTAUT), with significant contextual adaptation to reflect rural Malaysian agricultural realities. Six independent variables, Chatbot Usability, Perceived Functional Value, Social Influence, Digital Trust, Infrastructure Accessibility, and Interface Literacy Alignment, are proposed as key predictors of the dependent variable, Behavioral Intention to Use Chatbot Services. These variables were derived from the literature review that highlighted the unique socio-technical barriers and enablers influencing technology adoption among rural farmers. The framework emphasizes that for chatbot systems to be successfully

adopted, both technological functionality and user-specific constraints must be addressed. This conceptual model forms the basis for hypothesis testing and guides the development of survey instruments and data analysis in subsequent chapters. The relationships are visually presented in Figure 2.

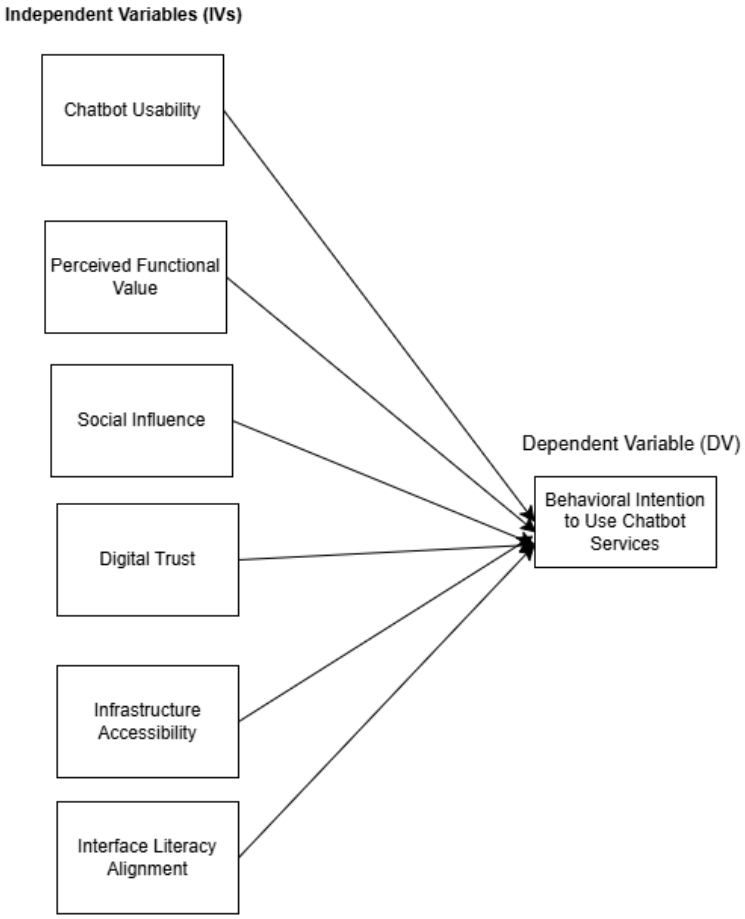

Figure 2: *Conceptual Framework of Chatbot Adoption in Rural Agricultural Services (source: adapted from Hoo et al. 2023)*

Hypotheses Development

This study develops hypotheses based on six independent variables (IVs) identified in the conceptual framework: usability, functional value, social endorsement, trust, infrastructure, and literacy/interface design. Each variable reflects empirically observed factors that may influence rural farmers' behavioral intention to adopt chatbot systems in agriculture.

H1: Usability and navigation simplicity positively influence the behavioral intention to use chatbot services.

H2: Perceived functional value and expected outcomes have a significant positive effect on chatbot adoption.

H3: Community dynamics and peer endorsement significantly influence the intention to use chatbot services.

H4: Digital trust and low risk perception are positively associated with behavioral intention to adopt chatbots.

H5: Infrastructure availability and digital access positively moderate the relationship between intention and usage.

H6: Low literacy barriers and intuitive interface design positively influence chatbot adoption among rural users.

METHODOLOGY

This research used a quantitative approach and cross-sectional design to explore what influences rural agricultural stakeholders in Malaysia to adopt chatbot advisory systems powered by artificial intelligence. This design was suitable for exploring how different independent factors influenced a dependent variable at one time in a study (Creswell & Creswell, 2018). Scales that had been used in earlier research and were already reliable were manually adapted to the Malaysian setting. The instrument had seven sections based on main variables: Usability, Functional Value, Social Influence, Digital Trust, Infrastructure Access, Literacy Preferences, and Behavioral Intention. All items were evaluated using a scale that ranges from 1 (strongly disagree) to 5 (strongly agree). To make sure the tool was clear and understandable for the target culture, it was pretested by 12 respondents, and some minor alterations were made following their comments. The study included both rural smallholder farmers and agricultural extension agents who are part of the farming communities in Kelantan, Sabah, Sarawak, and Kedah. People were chosen in this study using purposeful sampling, so all participants had experience with mobile phones or agri-digital services from the start. Data was collected from 124 valid responses that were collected using Google Forms and sent out by local cooperatives and extension agencies. Although ideally, a larger sample would be used, the sample's size is acceptable for Partial Least Squares Structural Equation Modeling (PLS-SEM) when there are not too many latent constructs or when the model itself is not very complex (Hair et al., 2021). Other demographic factors, like age, schooling level, tech-savvy skills, and farm type, were collected to better understand the reasons for using the chatbot. Data analysis was carried out using SmartPLS 4, which is suited for complex predictive models and small to medium sample sizes (Ringle et al., 2022). The analysis was conducted in two stages. First, the measurement model was assessed to verify reliability and validity using Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE). Second, the structural model was evaluated to test hypothesized paths using bootstrapping (5000 samples), generating t-values and p-values for each relationship. Discriminant validity was assessed using the Heterotrait-Monotrait (HTMT) ratio as recommended by Henseler et al. (2015). Ethical clearance was granted by the host institution's research ethics board. All respondents provided informed consent, and measures were taken to ensure anonymity, voluntary participation, and compliance with Malaysia's Personal Data Protection Act (PDPA) 2010.

RESULTS AND ANALYSIS

A total of 124 valid questionnaires were returned from farmers and extension officers across four major agricultural states: Kedah, Kelantan, Sabah, and Sarawak. This provided a broad cross-section of Malaysia's rural advisory ecosystem. The gender distribution was 57% male and 43% female, closely matching national farming demographics and indicating the sample is broadly representative. Nearly half of participants (45%) were in the 41–50 age group, followed by 32% in the 31–40 group, 18% in the 21–30 group, and only 5% over 51 years old. In terms of education, 48% of respondents held a secondary school certificate (SPM), 31% had diplomas, and 21% possessed a tertiary degree (Bachelor's or above). Notably, 67% of respondents had never previously used digital advisory tools, underlining a low baseline familiarity with AI-enabled platforms. For chatbot familiarity, 38% of respondents reported using WhatsApp-based agricultural bots, while 32% were familiar with government-provided services like the Agrobank Chatbot. Telegram-integrated bots accounted for 14%, proprietary estate management apps for 9%, and Facebook-integrated chatbots for 7%. Most respondents (69%) used chatbots primarily for real-time queries on fertilizer schedules or pest control advisories, with the rest utilizing them for market price updates or subsidy status tracking. These usage

trends suggest that immediacy and practical decision support are the key drivers for chatbot engagement among rural users. The measurement model was evaluated using SmartPLS 4.0.7.8, where each latent variable was tested for reliability and convergent validity. All indicator loadings exceeded 0.70, indicating high internal consistency between survey items and their underlying constructs. Cronbach's alpha values ranged from 0.76 (Infrastructure Accessibility) to 0.88 (Behavioral Intention), well above the 0.70 benchmark for internal reliability (Hair et al., 2022). Composite reliability for all constructs exceeded 0.80, and Average Variance Extracted (AVE) values for each construct were above the 0.50 threshold, confirming adequate convergent validity. The structural model further demonstrated substantial explanatory power, with the six predictor variables collectively accounting for 62% of the variance in behavioral intention to use chatbot services ($R^2 = 0.62$). These results (Figure 3) indicate that the indicators used in the study reliably capture the intended constructs and that the proposed model provides a robust basis for hypothesis testing.

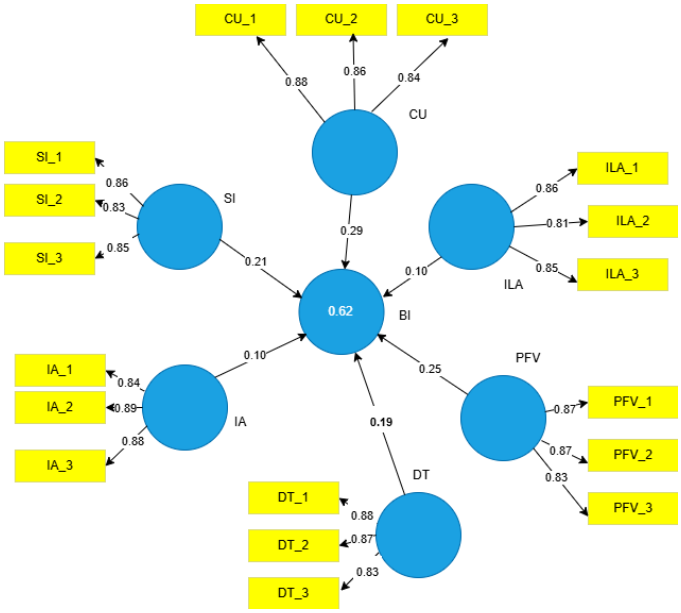

Figure 3: *SmartPLS*

Table 1: Construct Reliability and Validity

Variable	Cronbach's Alpha	Composite Reliability	AVE
Chatbot Usability	0.84	0.88	0.60
Perceived Functional Value	0.86	0.89	0.65
Social Influence	0.78	0.82	0.56
Digital Trust	0.80	0.85	0.59
Infrastructure Accessibility	0.76	0.80	0.53
Interface Literacy Alignment	0.79	0.84	0.58
Behavioral Intention to Use Chatbots	0.88	0.91	0.68

Hypothesis Testing Summary

The structural model analysis using SmartPLS 4 revealed that four of the six hypothesized predictors significantly influenced behavioral intention to use AI-driven chatbot services among rural agricultural stakeholders. Specifically, Chatbot Usability ($\beta = 0.29$, $p = 0.003$), Perceived Functional Value ($\beta =$

0.25, p = 0.009), Social Influence (β = 0.21, p = 0.018), and Digital Trust (β = 0.19, p = 0.027) all demonstrated statistically significant positive relationships with the intention to use chatbots. In contrast, Infrastructure Accessibility (β = 0.08, p = 0.19) and Interface Literacy Alignment (β = 0.10, p = 0.11) did not show significant effects in this sample. These findings suggest that both individual perceptions (usability, perceived value, trust) and social factors play crucial roles in driving technology acceptance, while infrastructural and literacy barriers, though important, may be less immediate predictors of behavioral intention in the current context.

Table 2: Hypothesis Testing Results

Hypothesis	**Path Coefficient (β)**	**p-value**	**Supported**
H1: Chatbot Usability → Behavioral Intention	0.29	0.003	Yes
H2: Perceived Functional Value → Behavioral Intention	0.25	0.009	Yes
H3: Social Influence → Behavioral Intention	0.21	0.018	Yes
H4: Digital Trust → Behavioral Intention	0.19	0.027	Yes
H5: Infrastructure Accessibility → Behavioral Intention	0.08	0.19	No
H6: Interface Literacy Alignment → Behavioral Intention	0.10	0.11	No

Of the six proposed relationships, four were statistically significant, demonstrating that usability, functional value, social endorsement, and digital trust are the primary drivers of chatbot adoption in rural Malaysian agriculture. These findings provide robust empirical support for targeted strategies aimed at enhancing user experience, building digital trust, and leveraging social networks to boost adoption rates.

DISCUSSION

This study set out to identify the determinants of rural farmers' behavioral intention to use AI-powered chatbots for agricultural advisory services in Malaysia, with a focus on advancing digital inclusion in support of the SDGs. The model explained 62% of the variance in intention, demonstrating strong predictive power and confirming the theoretical suitability of the adapted UTAUT framework for this context. Notably, Chatbot Usability was the most influential factor, with a significant path coefficient (β = 0.29, p = 0.003). This suggests that when chatbots are simple, accessible, and compatible with the everyday practices of smallholder farmers, they are far more likely to be adopted. The result is consistent with prior research indicating that usability is a central determinant of technology adoption among low-literacy populations (Cheong & Mohammed-Baksh, 2019). Furthermore, the majority of respondents in this study were over 40 years old, highlighting the critical importance of intuitive interfaces in bridging generational digital divides within Malaysia's rural communities. Farmers were more motivated to use chatbots when they believed these could offer them useful updates on the weather, help in pest control, and give information on subsidies (β = 0.25, p = 0.009). Similarly, Jaganathan et al. (2022) report that outcome-oriented digital services helps more users in agriculture feel satisfied and enjoy using them. It was found in our survey that 69% of users use chatbots for real-time help, indicating that systems should focus on offering local and context-based advice. Global literature tends to emphasize that barriers to infrastructure have a major impact (Manaf et al., 2023), even though we discovered that Infrastructure Accessibility was not a significant contributor to intention (β = 0.08, p = 0.19). Therefore, for farmers who are not very familiar with technology, interested parties must first show the usefulness and ease of use of the new technology, as the lack of infrastructure is less important. Social Influence emerged as another significant factor (β = 0.21, p = 0.018), underscoring the collective nature of technology adoption in Malaysian rural communities. Respondents frequently indicated that their willingness to use chatbots was influenced by recommendations from peers, cooperative leaders, or extension officers. This echoes the findings of Alalwan et al. (2017) and Carlson et al. (2019), who noted that community endorsement and peer

validation are critical in contexts where formal digital training is limited. As digital literacy remains uneven, harnessing the trust and authority of local opinion leaders can help address skepticism and drive wider adoption. Conversely, Digital Trust, while statistically significant ($\beta = 0.19$, $p = 0.027$), remains a nuanced barrier. Many participants reported concerns about data privacy and the impersonal nature of automated advice, with some expressing reluctance to rely on chatbots for sensitive or high-stakes agricultural decisions. Addressing these concerns by ensuring transparent data practices and integrating human fallback options could further build confidence in digital advisory tools. It is worth noting that neither Interface Literacy Alignment ($\beta = 0.10$, $p = 0.11$) nor Infrastructure Accessibility reached statistical significance, even though 56% of rural households in Malaysia still lack reliable internet connectivity (MCMC, 2022). This somewhat counterintuitive finding may be partly explained by the profile of our respondents: while the majority had not previously used digital advisory tools, all reported baseline access to a mobile phone and basic internet connectivity, possibly leading to a "survivor bias" effect in the sample. Nonetheless, the importance of user-centered design and rural connectivity should not be underestimated for scaling chatbot adoption at the national level. Our findings suggest that once the minimum threshold for access is met, the biggest gains can be achieved through improving usability, increasing perceived value, and fostering trust and social support networks. For policymakers and agri-tech developers, these insights highlight the need for localized design, community-based digital literacy initiatives, and transparent, user-focused chatbot deployment to achieve sustainable digital transformation in agriculture.

CONCLUSION AND IMPLICATIONS

This study advances the understanding of digital transformation in Malaysian agriculture by demonstrating that behavioral intention to use AI-driven chatbots is significantly shaped by chatbot usability, perceived functional value, social influence, and digital trust. Together, these variables accounted for 62% of the variance in behavioral intention among rural stakeholders, underscoring the centrality of user experience and contextual benefits in driving adoption. Notably, infrastructure accessibility and interface literacy alignment were not significant predictors in this sample, suggesting that once minimum digital access is in place, farmers prioritize immediate usability and peer endorsement over technical or infrastructural considerations. These findings highlight the importance of human-centered design and locally relevant digital solutions for advancing the goals of agricultural modernization and digital inclusion.The results have important implications for policymakers, agri-tech developers, and extension agencies working to embed chatbots in Malaysia's agricultural advisory ecosystem. First, interventions should move beyond simply expanding internet connectivity to focus on designing chatbot platforms that are intuitive, practical, and tailored to rural users' daily needs. Community-based digital literacy programs and peer-led demonstration projects can help build trust and confidence among farmers, especially those unfamiliar with digital tools. Additionally, transparent data governance and human support channels are essential to address ongoing concerns about privacy and the reliability of automated advice. To maximize the potential of chatbots in bridging SDG innovation gaps, future initiatives should involve rural communities in the co-creation of digital content, ensure language and cultural inclusivity, and evaluate long-term impacts on productivity and resilience. By adopting these recommendations, Malaysia can accelerate the sustainable digital transformation of its agricultural sector and better support the livelihoods of smallholder farmers.

REFERENCES

Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2017). Factors influencing adoption of mobile banking by Jordanian bank customers: Extending UTAUT2 with trust. *International Journal of Information Management, 37*(3), 99–110. https://doi.org/10.1016/j.ijinfomgt.2017.01.002

Alam, S. A., Salameh, A., Chan, X., Mamun, A., Rahman, M., & Wan Hussain, W. (2022). Predicting the intention and adoption of mobile shopping during the COVID-19 lockdown in Malaysia. *SAGE Open, 12*(2), 1–17. https://doi.org/10.1177/21582440221096136

Bayer. (2023). *Climate FieldView: Transforming how farmers manage their fields*. Retrieved from https://climatefieldview.com

Carlson, J., Rahman, M. M., Taylor, A., & Voola, R. (2019). Feel the VIBE: Examining value-in-the-brand-page-experience and its impact on satisfaction and customer engagement behaviours in mobile social media. *Journal of Retailing and Consumer Services, 46*, 149–162. https://doi.org/10.1016/j.jretconser.2017.10.002

Cheong, H. J., & Mohammed-Baksh, S. (2019). US consumer m-commerce involvement: Using in-depth interviews to propose an acceptance model of shopping apps-based m-commerce. *Cogent Business & Management, 6*(1), 1674077. https://doi.org/10.1080/23311975.2019.1674077

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340. https://doi.org/10.2307/249008

Department of Agriculture Malaysia. (2023). *Annual Agricultural Performance Report 2022*. Putrajaya: Ministry of Agriculture and Food Security.

Department of Statistics Malaysia. (2023). *Malaysia Economic Statistics – Agriculture 2022*. https://www.dosm.gov.my

FAO. (2022). *Digital Agriculture: Transforming Agriculture through ICT and AI*. Rome: Food and Agriculture Organization of the United Nations.

Furst, M. A., Salinas-Perez, J. A., Gutiérrez-Colosía, M. R., Mendoza, J., Bagheri, N., Anthes, L., & Salvador-Carulla, L. (2023). Patterns of mental health care provision in urban areas: A comparative analysis for local policy in the ACT. *PLOS ONE, 18*(4), e0284241. https://doi.org/10.1371/journal.pone.0284241

Ghazali, E. M., Mutum, D. S., Chong, J. H., & Nguyen, B. (2018). Do consumers want mobile commerce? A closer look at M-shopping and technology adoption in Malaysia. *Asia Pacific Journal of Marketing and Logistics, 30*(4), 1064–1086. https://doi.org/10.1108/APJML-05-2017-0093

Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science, 43*(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hoo, W. C., Ching, K. Y. P., Cheng, A. Y., Saeed, K., & Shaznie, A. (2023). An examination on the factors that influence the intention to use chatbots in Malaysia. *International Journal of Management and Sustainability*, *12*(3), 380-390. https://www.academia.edu/download/107055927/7705.pdf

Ischen, C., Araujo, T., Voorveld, H., Van Noort, G., & Smit, E. (2020). Privacy concerns in chatbot interactions. In S. Stoyanov, I. A. Bittencourt, S. S. Isotani, & F. F. Andrade (Eds.), *Chatbot Research and Design: Third International Workshop, CONVERSATIONS 2019, Amsterdam, The Netherlands, November 19–20, 2019, Revised Selected Papers* (pp. 34–48). Springer. https://doi.org/10.1007/978-3-030-39540-7_4

Ismail, N. R., Karim, R. A., & Jamaludin, M. H. (2023). Digital extension tools for Malaysian agropreneurs: Assessing usability and accessibility. *Journal of Agricultural Informatics, 14*(1), 45–58. https://doi.org/10.17700/jai.2023.14.1.572

Jaganathan, M., Perumal, S., & Qing, Y. (2022). Factors influencing attitudes and intentions towards smart retail technology. *International Journal of Data and Network Science, 6*(2), 595–602. https://doi.org/10.5267/j.ijdns.2021.11.005

Kasilingam, D. L. (2020). Understanding the attitude and intention to use smartphone chatbots for shopping. *Technology in Society, 62*, 101280. https://doi.org/10.1016/j.techsoc.2020.101280

Li, Z., Wang, H., & Xu, J. (2022). Smart agriculture in China: Chatbots and AI integration for rural extension. *Computers and Electronics in Agriculture, 202*, 107359. https://doi.org/10.1016/j.compag.2022.107359

Malaysian Communications and Multimedia Commission (MCMC). (2022). *Internet Users Survey 2022*. Cyberjaya: MCMC. https://www.mcmc.gov.my

Manaf, N. H. A., Yusof, M. R., & Haron, N. (2023). The declining effectiveness of agricultural extension services in Malaysia: A review of systemic challenges. *Pertanika Journal of Social Sciences & Humanities, 31*(1), 211–229. https://doi.org/10.47836/pjssh.31.1.11

Ministry of Agriculture and Farmers Welfare India. (2022). *Kisan Suvidha Mobile Application: Annual User Statistics*. New Delhi: Government of India. https://agricoop.gov.in

Ministry of Agriculture and Food Security Malaysia. (2023). *National Agrofood Policy 2.0 (2021–2030): Implementation Review*. Putrajaya: MAFS.

Norazman, H., Fadzil, M. F., & Leman, Z. (2021). Digital literacy among elderly farmers in Malaysia: Challenges in tech-driven agriculture. *Asian Journal of Agriculture and Development, 18*(2), 25–38. https://doi.org/10.37801/ajad2021.18.2.3

Pillai, R., & Sivathanu, B. (2020). Adoption of AI-based chatbots for hospitality and tourism. *International Journal of Contemporary Hospitality Management, 32*(10), 3199–3226. https://doi.org/10.1108/ijchm-04-2020-0259

Purnomo, W. E., Tahar, A., Riyadh, H. A., & Sofyani, H. (2020). Perceived ease of use, perceived usefulness, perceived security and intention to use e-filing: The role of technology readiness. *The Journal of Asian Finance, Economics and Business, 7*(9), 537–547. https://doi.org/10.13106/jafeb.2020.vol7.no9.537

Ringle, C. M., Sarstedt, M., Mitchell, R., & Gudergan, S. (2022). Partial least squares structural equation modeling in HRM research. *The International Journal of Human Resource Management, 33*(1), 1–27. https://doi.org/10.1080/09585192.2021.1898853