Emerging Trends and Challenges in Contemporary Management Integrating Digital Transformation, Sustainability and Human Factors for Organizational Development

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ABSTRACT

This review investigates the integration of advanced digital technologies and sustainable pest management strategies to enhance halal supply chain integrity and food safety. Emphasizing the critical importance of halal compliance for Muslim consumers, the paper examines challenges in maintaining traceability and preventing contamination within complex supply chains. Key digital innovations such as blockchain technology, Internet of Things (IoT), artificial intelligence (AI), and emerging platforms like the metaverse are discussed for their roles in ensuring transparency, data integrity, and real-time monitoring. Concurrently, sustainable pest management approaches including biological control agents, integrated pest management (IPM), and data-driven monitoring systems are reviewed for their effectiveness against invasive pests impacting halal food sources. The synthesis highlights synergies between technological solutions and sustainable practices that collectively improve compliance, risk assessment, and consumer trust. Implementation challenges, particularly for small and medium enterprises and institutional barriers are identified, guiding future research directions focusing on technological scalability, regulatory readiness, ecological efficacy of pest control agents and consumer engagement. Overall, the review underscores the potential of combining digital innovations with sustainable pest management to fortify halal supply chains and promotes multidisciplinary efforts to address existing gaps.

Keywords: halal supply chain integrity, blockchain technology, sustainable pest management, biological control, food safety, Internet of Things, artificial intelligence, integrated pest management

INTRODUCTION

Context and Importance of Halal Supply Chain Integrity

The halal supply chain is vital for Muslim consumers who require assurance that their food and related products comply with Islamic dietary laws. Maintaining halal integrity involves ensuring that products are free from contamination and possess transparent halal certification throughout complex supply chains (Ismail et al., 2025; Usman et al., 2022). However, maintaining traceability and halal assurance is challenging due to vulnerabilities in supply chains, risks of cross-contamination with non-halal products, and inefficiencies in certification systems (Saktia Ardiantono et al., 2024; Usman & Vanany, 2024). Food safety concerns further compound these challenges, necessitating rigorous controls to address both halal compliance and safety risks (Wahyuni et al., 2024; Hana Wahyuni et al., 2024).

Emerging Challenges: Pest Management and Food Safety

In addition to certification and operational challenges, the halal food supply chain confronts risks from invasive pests like the brown marmorated stink bug (Halyomorpha halys), which adversely affects crop quality and yield, threatening food safety and the availability of halal sources (Rolando et al., 2025; Palazzetti et al., 2024). Pestinduced damages can compromise the physical and chemical integrity of food crops, potentially impacting halal compliance when these crops serve as raw inputs. Effective pest management is thus an essential component of ensuring overall halal food safety and quality.

Advanced Digital Technologies in Halal Supply Chain Integrity

Blockchain Technology for Traceability and Compliance

Blockchain technology offers potent solutions for enhancing halal supply chain transparency and trust through immutable, decentralized data recording that prevents fraud and data tampering (Mohammad Farid Azlan et al., 2025; Purusottama & Sunitiyoso, 2023). Models like HalalChain by Yakubu et al. (2025) utilize cryptography, IoT integration, and smart contracts to ensure real-time halal compliance, tamper-proof certification, and automated tracking, thereby improving operational efficiency and consumer confidence. Adhiwibowo et al. (2025) demonstrate dual blockchain systems combined with point of authority consensus to provide holistic halal traceability particularly in fresh meat supply chains. Nonetheless, adoption challenges persist: regulatory bodies exhibit varying degrees of readiness, and consumer acceptance hinges on ease of application and awareness, as shown by Karyani et al. (2024) and Purusottama & Simatupang (2025).

Internet of Things, AI, and Digital Innovations

Beyond blockchain, real-time compliance monitoring leverages IoT-based sensors and devices to track product conditions and supply chain events, integrating with smart contracts to automate halal regulation compliance (Adhiwibowo et al., 2025; Ellahi et al., 2025). AI and machine learning applications enhance logistics and supply chain performance by predicting disruptions, optimizing routes, and improving traceability analytics (Sumarliah & Al-hakeem, 2023; Fernando et al., 2024). In pest management, advanced drone-based monitoring combined with RGB cameras and deep learning algorithms enables accurate detection of H. halys infestations, facilitating timely interventions with minimal environmental footprint (Palazzetti et al., 2024; Betti Sorbelli et al., 2023; Kargar et al., 2024).

Metaverse and Digital Experience Enhancement

Emerging digital platforms such as the metaverse present opportunities to simulate and visualize halal supply chain operations and consumer interactions, enriching consumer engagement and providing new avenues for consumer behavior tracking and market insights (Fernando et al., 2024).

Conceptual framework

To synthesize the fragmented findings of prior studies and address the lack of an integrated perspective, this study proposes a conceptual framework that visually illustrates the interrelationships between digital transformation, human factors, and sustainability outcomes. Rather than treating these dimensions in isolation, the framework conceptualizes them as a dynamic and interconnected system that shapes organizational development in contemporary management contexts.

As shown in figure 1, digital transformation serves as the primary strategic driver, while human factors function as a critical mediating mechanism that enables or constrains the realization of sustainability outcomes. The framework further incorporates transformation enablers, barriers, and adaptive leadership as overarching mechanisms that influence the effectiveness and direction of digital transformation initiatives across service, manufacturing, and knowledge-based industries.

Figure 1

Source : Developed by the authors based on prior studies (Purusottama & Sunitiyoso, 2023; Sumarliah & Alhakeem, 2023; Yakubu et al., 2025; Karyani et al., 2024; Wahyuni et al., 2024).

The framework highlights that advanced digital technologies alone are insufficient to deliver sustainable organizational outcomes. Instead, adaptive leadership, digital skills, and organizational culture play a pivotal role in translating technological capabilities into halal compliance, food safety assurance, and long-term organizational resilience. This integrated perspective provides a foundation for the subsequent discussion, which is structured around transformation enablers, barriers, and adaptive leadership.

Sustainable Pest Management Approaches in Halal Food Systems

Biological Control and Integrated Pest Management (IPM)

Biological control via egg parasitoids such as Trissolcus japonicus and Trissolcus mitsukurii shows promise in suppressing H. halys populations, thereby protecting important halal crop sources (Mele et al., 2025; Naghavi et al., 2025). The use of inter-row flowering ground covers like buckwheat enhances parasitoid activity by providing nectar resources, improving parasitism rates and contributing to natural pest population regulation (Mele et al., 2025). Augmentative releases of native parasitoids such as Anastatus bifasciatus have demonstrated increased parasitism without negative ecological impacts, highlighting a viable control approach (Iacovone et al., 2022).

Chemical and Physical Control Measures

While fungicides and plant strengtheners are used to protect crops, their sub-lethal and lethal effects on beneficial parasitoids must be carefully managed to avoid undermining biological control agents (Mele et al., 2025). Physical control methods, like exclusion netting, also contribute significantly; factors such as net color and timing of deployment influence effectiveness against stink bug infestations, enabling reductions in pesticide application while safeguarding crop quality (Fornasiero et al., 2023).

Data-Driven Pest Monitoring and Forecasting

Real-time data platforms integrating trap networks and sensor data support better forecasting and decision making to optimize sustainable pesticide use and reduce crop damage (Forresi et al., 2024). Innovative low power edge computing systems for automated pest detection increase feasibility and accessibility for orchard monitoring, providing timely and accurate pest status reports to farmers (Kargar et al., 2024).

Integrating Advanced Technologies with Sustainable Pest Management for Halal Supply Chain Enhancement

Synergies Between Digital Traceability and Pest Management

Integrating pest management data into blockchain and IoT platforms enriches halal supply chain transparency by documenting pest control activities, pesticide usage, and infestation events with immutable timestamps

(Yakubu et al., 2025; Adhiwibowo et al., 2025). Machine learning-enhanced predictive analytics can forecast pest outbreaks driving proactive intervention scheduling and quality control, thereby supporting halal compliance and sustainability goals (Sumarliah & Al-hakeem, 2023).

Enhancing Food Safety and Halal Compliance through Technology and Sustainable Practices

Risk analysis frameworks that combine food safety and halal compliance evaluations benefit from block chain enabled traceability systems, which facilitate hazard detection and rapid responses (Wahyuni et al., 2025). Such integrations enhance consumer trust and sustainability outcomes, while positively impacting business competitive performance and supply chain resilience (Kurniawati & Vanany, 2024; Azam et al., 2025).

Challenges and Opportunities in Implementation

Despite technological promise, small and medium-sized enterprises face barriers including high initial costs, limited technological capabilities, and stringent regulatory demands (Kurniawati et al., 2023; Sari et al., 2024). Institutional and policy frameworks, as well as education and awareness, strongly influence adoption rates and effectiveness of halal technology and pest management innovations (Darmalaksana, 2023; Kurniawati et al., 2022).

Future Research Directions

Technological Innovations and Scalability

Exploration of integrated Industry 4.0 frameworks combining blockchain, AI, IoT, cloud computing, and digital twins is critical to scale halal supply chain solutions and improve resilience (Ellahi et al., 2026). Similarly, advancing virtual platforms like the metaverse can enrich consumer engagement and supply chain transparency (Fernando et al., 2024).

Expanding Sustainable Pest Management Research

Further ecological and efficacy studies of biological control agents across diverse regions and crops are needed to optimize integrated pest management in halal food systems (Mele et al., 2025; Iacovone et al., 2022). Research integrating pest management data directly within blockchain-enabled supply chains holds promise for enhancing holistic halal assurance.

Policy and Stakeholder Engagement

Examining regulatory readiness, certification agency capabilities, and stakeholder collaborations is essential to align halal compliance with emerging digital technologies while ensuring inclusivity, particularly for SMEs (Karyani et al., 2024; Purusottama & Simatupama, 2025).

Consumer Behavior and Market Impact

Evaluating how enhanced transparency, traceability, and pest management impact consumer trust and purchase intentions remains crucial. Considering cultural and regional diversity in halal supply chain technology acceptance can guide tailored marketing and policy strategies (Ismail et al., 2025; Shah et al., 2025).

CONCLUSION

The integration of advanced digital technologies with sustainable pest management presents a promising multidimensional approach to strengthening halal supply chain integrity and ensuring food safety. Blockchain, IoT, AI, and digital innovations enhance transparency, traceability, and real-time monitoring, addressing key challenges of halal compliance and contamination risks. Concurrently, sustainable pest management strategies, particularly biological control and integrated pest management, mitigate invasive pest threats while supporting ecological balance. Despite clear synergies, implementation faces barriers including technological readiness, cost constraints, and regulatory challenges, especially among small and medium enterprises. Future efforts must focus on advancing scalable Industry 4.0 frameworks, refining biological control efficacy across diverse contexts, and fostering institutional and consumer engagement. Addressing these gaps will not only improve halal assurance but also enhance sustainability and competitiveness within global food systems, marking a critical pathway for research, policy development, and practical applications in halal supply chains.

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