Bridging Industry 4.0 and Halal Competencies: Towards Human Capital Readiness in Malaysia

Mohd Fauzi Kamarudin[1,*], Zuhud Rozaki[2], Triyono Triyono[3], Muhammad Ridzuan Bin Noorzelan[4], Nurul Aliah Mustafa[5]

[1,4]Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia

[2,3]Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

[5]Faculty of Education, University College MAIWP International, Kuala Lumpur, Malaysia

***Corresponding Author**

DOI: https://doi.org/10.47772/IJRISS.2026.101000030

Received: 07 October 2026; Accepted: 12 October 2026; Published: 28 October 2026

ABSTRACT

Industry 4.0 is reshaping the nature of work and the human capital that organisations require, yet discussions of readiness in the Malaysian Halal industry still tend to emphasise digital and technical competencies while giving less attention to how these combine with Halal-specific competencies. This paper examines how insights from youth employability research in the Industry 4.0 job market can be extended to explain human capital readiness in the Malaysian Halal industry. Using Qualitative Secondary Analysis supported by framework synthesis, an earlier grounded theory dataset drawn from industry practitioners, entrepreneurs, government agencies and academics was mapped against Halal human capital requirements identified in literature published between 2022 and 2026. Each original theme was classified as retained, contextualised, expanded or additional, and the resulting competencies were defined, grouped into four domains and prioritised against explicit criteria. Most themes remain relevant but take on a different meaning in the Halal context. Halal compliance awareness, traceability and data integrity, data analytics and Halal-sensitive problem-solving emerge as core competencies, followed by digital Halal quality management, automation oversight and ethical decision-making. The paper argues that technology adoption does not by itself deliver readiness: it creates competency demands, and it is the dual competency of the workforce, enabled by leadership, continuous learning, organisational support and collaboration among industry, government and higher education institutions, that determines whether Halal integrity is maintained in technology-enabled operations. A conceptual framework of Halal–Industry 4.0 Human Capital Readiness, testable propositions and a stakeholder validation design are proposed. The study extends Industry 4.0 employability insights into the Halal context and offers implications for Halal organisations, policymakers and higher education institutions.

Keywords: Halal Industry, Human Capital, Halal Competencies, Digital Competencies, Talent Management

INTRODUCTION

Industry 4.0 refers to the convergence of digital and physical systems through technologies such as artificial intelligence, the Internet of Things (IoT), big data analytics, cloud computing, automation and blockchain. These technologies change how organisations operate and, more importantly, what they expect from the people who work in them. Recent Malaysian evidence shows that employers place a very high value on digital skills when hiring entry-level graduates, yet graduates continue to show measurable gaps in communication and collaboration, problem-solving and digital safety (Tee et al., 2024). Human capital has therefore become a central concern of Industry 4.0 transformation, alongside investment in technology itself.

The Halal industry is not insulated from these shifts. Malaysia has positioned itself as a global Halal hub, and the sector has been reported to contribute around 7.8 per cent of national gross domestic product (Hadis et al., 2025). At the same time, the integrity of Halal products remains a recurring concern. Cases such as the Halal meat cartel scandal revealed by Malaysian media have intensified calls for stronger traceability, verification and transparency across Halal supply chains (Ellahi et al., 2025). Industry 4.0 technologies are increasingly viewed as part of the solution, but their effectiveness depends on the people who design, operate, monitor and make decisions with them.

This is where a gap emerges. Discussions on Industry 4.0 readiness tend to emphasise digital and technical competencies, whereas work on the Halal profession concentrates on Halal knowledge, certification and compliance (Abidin et al., 2026; Ahmad et al., 2024), and in Malaysia the competencies of the Halal executive had yet to be clearly defined (Rosli et al., 2022). A graduate who is digitally capable but unfamiliar with Halal requirements may unintentionally compromise Halal integrity when operating automated systems. Conversely, a Halal executive with strong religious and regulatory knowledge may struggle to work with data-driven and digitally enabled processes.

Research gap and originality

Three bodies of work are relevant, and Table 1 summarises what each establishes and what it leaves open. Industry 4.0 readiness and employability studies document digital skill demand, skill gaps and the organisational conditions for adoption (Jayashree et al., 2022; Tee et al., 2024; Wong & Kee, 2022), but they do not specify what Halal competence adds. Halal human capital studies describe the competencies of Halal executives and the demand for Halal skills (Abidin et al., 2026; Ahmad et al., 2024; Rosli et al., 2022; Tukiran et al., 2025), with less evidence on how these combine with data, automation and digital quality capabilities. Halal technology studies examine tools and adoption (Albawardi et al., 2026; Ellahi et al., 2025; Hadis et al., 2025; Musadik, 2024), yet the workforce appears mainly as a barrier rather than as an object of analysis. Albawardi et al. (2026) call for research on hybrid digital–Halal skill development, which indicates that the gap is recognised but not yet addressed.

Table 1. Positioning of this study against related research streams

Research stream	Representative studies	What it establishes	What remains missing
Industry 4.0 readiness and youth employability	Jayashree et al. (2022); Kamarudin et al. (2025); Tee et al. (2024); Wong & Kee (2022)	Digital skill demand and gaps; organisational capabilities, support and leadership as drivers of readiness	No account of what Halal competence adds; Halal requirements are not treated as a competency dimension
Halal human capital and competencies	Abidin et al. (2026); Ahmad et al. (2024); Kudus et al. (2025); Rosli et al. (2022); Tukiran et al. (2025)	Halal executive competencies, talent gaps and skills demand in the Halal profession	Focus on the Halal executive role; limited classification or prioritisation of integrated digital–Halal competencies for youth entering the workforce
Halal technology and adoption	Albawardi et al. (2026); Ellahi et al. (2025); Hadis et al. (2025); Musadik (2024); Yahya et al. (2023); Ziegler et al. (2024)	Technology options (RFID, blockchain, IoT, AI), adoption drivers and barriers, including workforce readiness	Workforce treated as a background condition; the link between adoption, competencies and readiness is not explained analytically
This study	Qualitative secondary analysis of a multi-stakeholder youth employability dataset, mapped against Halal literature (2022–2026)	Defines and classifies competencies, prioritises them against explicit criteria, and explains how adoption, competencies and readiness relate	Empirical validation with Halal-certified businesses, experts, educators and employees (proposed)

The paper makes four contributions. First, it re-reads multi-stakeholder youth employability evidence through a Halal lens, instead of starting from the Halal sector alone. Unlike Ahmad et al. (2024), who align competencies for the Halal executive role, it starts from the youth who will enter technology-enabled Halal work. Second, it defines and classifies the relevant competencies into four domains. Third, it prioritises them against explicit and transparent criteria, giving organisations and educators an ordered agenda. Fourth, it explains analytically how technology adoption, workforce competencies and human capital readiness are related, and states testable propositions. To the authors' knowledge, this combination has not been presented for the Malaysian Halal industry.

The paper builds on an earlier grounded theory study of youth employability readiness for the IR4.0 job market, which drew on industry practitioners, entrepreneurs, government agencies and academics (Kamarudin et al., 2025). Using Qualitative Secondary Analysis (QSA) supported by framework synthesis, it revisits that dataset through the lens of the Malaysian Halal industry. It aims to:

(a) revisit the key youth employability insights for the Industry 4.0 job market reported in the original study;

(b) define and classify the Industry 4.0, Halal-specific and integrated competencies relevant to the Malaysian Halal industry;

(c) map the original themes against Halal requirements and prioritise the resulting competencies; and

(d) develop a conceptual framework explaining how technology adoption, competencies and human capital readiness are related.

LITERATURE REVIEW

Industry 4.0 and youth employability

Employability in the Industry 4.0 era is shaped by how quickly the skills demanded by employers change. Tee et al. (2024) surveyed 376 companies registered with the Malaysian Productivity Corporation and found that information and data literacy, problem-solving and digital content creation were the most demanded digital skills at present, while problem-solving, safety, and communication and collaboration were expected to become the most important. The largest skill gaps were in communication and collaboration, followed by problem-solving and safety. Employability therefore depends not only on technical familiarity but also on the ability to apply digital tools to real work situations.

Organisational conditions matter as well. In a study of 314 Malaysian small and medium enterprises (SMEs), Jayashree et al. (2022) found that IT resources, management leadership, teamwork and external support significantly influenced Industry 4.0 adoption. Wong and Kee (2022), surveying owners and managers of manufacturing SMEs that had received government assistance, found that organisational capabilities, institutional support and market factors were positively associated with Industry 4.0 readiness. Employability is thus produced jointly by the individual, the organisation and the wider support ecosystem. Kamarudin et al. (2025) approached the question through grounded theory and surfaced themes of Industry 4.0 awareness, digital competencies, adaptability, problem-solving, innovation, organisational readiness, leadership, and the need for structured coaching and support. These themes are the starting point for the Halal-oriented analysis in this paper.

Human capital and technology in the Halal industry

The Halal industry depends on competent people at every stage of Halal assurance. Ahmad et al. (2024) describe the Halal executive as a pivotal professional who must ensure compliance with Halal principles while adapting to the challenges and opportunities of IR4.0 technologies. Labour-market evidence points the same way. Abidin et al. (2026) analysed 200 Halal industry job postings together with Halal studies programme standards in Malaysia and reported demand for specialised skills and industry-relevant knowledge, with stakeholders wanting graduates who combine theoretical foundations with practical competencies. A

systematic review of Halal talent development in Malaysia likewise points to the need to align educational and organisational strategies with industry needs and to strengthen technological and educational support for Halal compliance (Tukiran et al., 2025). A recent review of digital transformation in Halal human resource development adds that digital tools can enhance training and support ethical decision-making provided that technological innovation is balanced with Shariah compliance (Kudus et al., 2025).

Halal industry development in Malaysia has created both opportunity and pressure for firms. A systematic review of 79 articles published between 2013 and 2023 identified a spectrum of challenges facing Malaysian Halal food SMEs (Saima et al., 2024). In Halal food manufacturing, Musadik (2024) reports that RFID is the most advanced technology for monitoring and verifying Halal items, while blockchain is still at an early stage of application. Albawardi et al. (2026) add that Halal food manufacturers face a non-negotiable layer of compliance and certification integrity, that adoption is constrained by cost, legacy systems, workforce readiness, compliance complexity and policy awareness, and that workforce training must embed Halal compliance understanding so that technology use does not inadvertently violate Halal procedures.

A growing body of work explores how Industry 4.0 technologies can strengthen Halal integrity. Ellahi et al. (2025) reviewed their use in the Halal meat supply chain, highlighting augmented reality for real-time verification, the metaverse for virtual inspections, artificial intelligence and robotics for efficiency, compliance and hygiene, and digital twins for training and quality monitoring, while noting that few studies have examined practical implementation. Ziegler et al. (2024) concluded that blockchain-based solutions may increase visibility, trust and accountability in Halal supply chains, although implementation poses real hurdles. Adoption is not automatic: in a survey of 245 Malaysian food and beverage SMEs, Hadis et al. (2025) found that perceived usefulness, top management support, government support and competitor pressure positively influenced the intention to adopt Halal traceability systems, whereas perceived ease of use and employee training were negatively associated with it, which the authors read as a sign that complexity and insufficient training can hinder uptake. In a survey of 218 managers of Halal food SMEs in East Coast Malaysia, Yahya et al. (2023) found that coercive and normative pressures significantly affected the intention to adopt IR 4.0 technologies, whereas mimetic pressure did not.

Synthesis: from youth employability to Halal industry skills

Table 2 brings the two streams of literature together. It shows that most generic employability themes have a Halal-specific counterpart, but that the Halal counterpart adds a requirement of religious and regulatory sensitivity.

Table 2. Youth employability research and corresponding Halal industry skills

Youth Employability Research	Halal Industry Skills	Reference
Digital competency. Employers rate digital skills as very important for entry-level graduates; information and data literacy and digital content creation are in highest current demand.	**Digital + Halal competency.** Halal professionals must pair digital capability with Halal knowledge and be able to interpret data dashboards; Halal executives need competencies aligned with IR4.0.	Ahmad et al. (2024); Albawardi et al. (2026); Kamarudin et al. (2025); Tee et al. (2024)
Technology readiness. IT resources, management leadership, organisational capabilities and external support drive Industry 4.0 adoption and readiness in SMEs.	**Technology + Halal process readiness.** RFID, blockchain, IoT, AI, digital twins and AR are being explored for Halal traceability, verification and monitoring; institutional pressures shape SME intention to adopt IR 4.0.	Albawardi et al. (2026); Ellahi et al. (2025); Jayashree et al. (2022); Musadik (2024); Wong & Kee (2022); Yahya et al. (2023); Ziegler et al. (2024)
Problem-solving. The most demanded digital skill for the future, with one of the largest graduate skill gaps.	**Halal-sensitive problem-solving.** Staff must address cross-contamination, fraud and traceability problems without compromising Halal status.	Ellahi et al. (2025); Tee et al. (2024)

Innovation. Innovation and awareness of new technologies are part of employability readiness in the IR4.0 job market.	**Halal innovation capability.** AR verification and digital twins for training offer new ways to deliver Halal assurance.	Ellahi et al. (2025); Kamarudin et al. (2025)
Adaptability. Rapid technological change requires graduates who can adjust to new tools and work practices.	**Adaptability within Halal requirements.** Halal executives must adapt to IR4.0 challenges while remaining compliant with Halal principles.	Ahmad et al. (2024); Kamarudin et al. (2025)
Organisational compliance. Digital safety and organisational readiness are required for responsible technology use.	**Halal compliance awareness.** Job postings and programme standards emphasise specialised Halal knowledge; core competency models for Halal executives are being defined.	Abidin et al. (2026); Rosli et al. (2022); Tee et al. (2024)
General ethics. Ethical conduct is expected in digital work environments.	**Halal integrity and ethical decision-making.** Integrity, transparency and trust are central to Halal supply chains using digital systems.	Ellahi et al. (2025); Ziegler et al. (2024)
Continuous learning. Skill demands shift over time, so graduates and employees need ongoing upskilling.	**Integrated technology–Halal learning.** Practical training, competency-based learning and employee training are needed; digital tools can support Halal-aligned training.	Abidin et al. (2026); Hadis et al. (2025); Kudus et al. (2025); Tukiran et al. (2025)
Industry support. External support and structured coaching help organisations and youth to become ready.	**Halal ecosystem support and coaching.** Government support and industry collaboration encourage adoption of Halal technologies and curriculum alignment.	Hadis et al. (2025); Jayashree et al. (2022); Kamarudin et al. (2025); Yahya et al. (2023)

CONCEPTUAL DEFINITIONS AND COMPETENCY CLASSIFICATION

Terms such as digital skills, Halal competence and readiness are often used loosely. This paper therefore adopts the following working definitions, which are analytical rather than regulatory. Human capital readiness is the degree to which the workforce possesses, and can deploy, the competencies demanded by technology-enabled Halal operations. Halal integrity is the assurance that products, processes and records remain consistent with Halal requirements across the supply chain. Dual competency is the integrated capability to use digital and technological tools effectively while applying Halal knowledge and judgement within the same task.

Competencies are classified into four domains (Table 3). Domains A and B contain the Industry 4.0 competencies, separated into technological and adaptive–collaborative groups. Domain C contains the Halal-specific competencies. Domain D contains the integrated competencies that arise only where the two sets meet, and it is these that operationalise dual competency. The classification is derived from the sources shown and from the themes of the original study.

Table 3. Classification and working definitions of competencies

Domain	Competency	Working definition	Basis
A. Industry 4.0 technological	Digital and data analytics competency	Ability to find, evaluate, create and protect information with digital tools and to interpret dashboards, sensor and transaction data to support decisions	Albawardi et al. (2026); Tee et al. (2024)
	Automation and smart-systems competency	Ability to operate, monitor and maintain automated, sensor-based and AI-enabled equipment and to respond to system alerts	Albawardi et al. (2026); Ellahi et al. (2025)
B. Industry 4.0 adaptive and collaborative	Problem-solving	Ability to diagnose and resolve non-routine problems using digital information	Tee et al. (2024)

	Innovation and adaptability	Ability to apply new tools and adjust work practices as technologies change	Ahmad et al. (2024); Kamarudin et al. (2025)
	Continuous learning	Ongoing updating of technical and Halal knowledge through practical, competency-based learning	Abidin et al. (2026); Hadis et al. (2025)
	Communication and collaboration	Ability to share information and coordinate work across teams and organisations	Tee et al. (2024)
C. Halal-specific	Halal knowledge	Understanding of Halal principles, standards and certification requirements	Abidin et al. (2026); Rosli et al. (2022)
	Halal process understanding	Understanding of how sourcing, segregation, hygiene and documentation protect Halal status at each process step	Albawardi et al. (2026)
	Halal compliance awareness	Awareness of documentation, audit and certification obligations and of the consequences of non-compliance	Abidin et al. (2026); Albawardi et al. (2026)
	Halal integrity and ethical decision-making	Commitment and ability to protect transparency and trust, including deciding whether doubtful inputs are accepted, flagged or rejected	Ellahi et al. (2025); Ziegler et al. (2024)
D. Integrated (dual competency)	Halal traceability and data integrity	Ability to use traceability systems (e.g., RFID, blockchain, IoT) and to verify that records remain accurate and complete	Ellahi et al. (2025); Hadis et al. (2025); Musadik (2024); Ziegler et al. (2024)
	Digital Halal quality management	Ability to use digital monitoring, audit trails and quality data to control Halal-critical points	Albawardi et al. (2026); Ellahi et al. (2025)
	Halal-sensitive automation oversight	Ability to supervise automated or AI-supported processes so that they stay within Halal requirements, and to intervene when they deviate	Albawardi et al. (2026); Ellahi et al. (2025)
	Halal-sensitive problem-solving	Ability to resolve technical problems while treating Halal integrity as a boundary condition	Ellahi et al. (2025); Tee et al. (2024)

METHODOLOGY

Research design

This study adopts Qualitative Secondary Analysis (QSA), which involves the re-use of existing qualitative data to address a new research question (Heaton, 2004, 2008). QSA was chosen for three reasons: the original dataset already captured the perspectives of several stakeholder groups on what makes youth ready for the Industry 4.0 job market; those perspectives can be examined again from a different analytical angle without burdening participants; and the aim is theory-building, for which a transparent re-analysis is appropriate. The analysis is supported by framework synthesis (Carroll et al., 2013), in which an a priori framework is used to organise and interrogate evidence and is then adjusted where the evidence does not fit.

Original dataset and stakeholder coverage

The dataset comes from an earlier grounded theory study of youth employability readiness and sustainability in the IR4.0 job market (Kamarudin et al., 2025). Its participants came from four stakeholder groups: industry practitioners, entrepreneurs, government agencies and academics. Eight in-depth interviews and seven Focus Group Discussions (FGDs) were conducted using purposive sampling techniques to obtain diverse stakeholder perspectives on youth

employability and workforce readiness in the Industry 4.0 era. Its principal themes were Industry 4.0 awareness, digital competencies, adaptability, problem-solving, innovation, organisational readiness, leadership, and structured coaching and support. No new participants were recruited for the present analysis. Table 4 shows how the stakeholder groups relevant to the Halal industry are covered by the original dataset and by the 2022–2026 literature.

Table 4. Stakeholder coverage of the evidence base

Stakeholder group	Original dataset	2022–2026 literature	Role in this paper
Halal-certified businesses and entrepreneurs	Entrepreneurs (not Halal-specific)	Hadis et al. (2025): 245 food and beverage SMEs; Wong & Kee (2022): 110 manufacturing SME owners and managers; Yahya et al. (2023): 218 Halal food SME managers	Adoption barriers, training gaps and institutional pressures; direct validation proposed
Industry experts, practitioners and agencies	Industry practitioners and government agencies	Ahmad et al. (2024); Albawardi et al. (2026); Rosli et al. (2022): Halal executive competencies and adoption challenges	Competency definitions; expert validation proposed
Educators and academics	Academics	Abidin et al. (2026): programme standards and 200 job postings; Tukiran et al. (2025): talent development gaps	Supply-side alignment; curriculum validation proposed
Employees and graduates	Youth readiness captured through the four groups above	Abidin et al. (2026): job postings; Tee et al. (2024): 376 employers on graduate skill gaps	Demand-side skill gaps; employee survey proposed

Literature corpus

Literature published between 2022 and 2026 was identified through searches of Google Scholar and publisher and institutional repository platforms, using combinations of the terms Halal, Industry 4.0, IR4.0, human capital, competency, skills, talent, traceability, digital and Malaysia. Sources were retained if they were peer-reviewed journal articles, book chapters or conference papers; addressed Halal human capital, Halal technology adoption, or Industry 4.0 readiness and employability; and were Malaysian in context or directly relevant to it. Sixteen sources met these criteria. The selection is purposive rather than exhaustive, consistent with framework synthesis, which aims to build and test a framework rather than to enumerate all studies.

Analytical procedure

The analysis followed five steps:

1. **Familiarisation and theme extraction.** The themes and supporting data of the original study were re-read with the new question in mind, and each theme was recorded together with its stakeholder source.

2. **Framework development.** An a priori framework of Halal human capital requirements was built from the literature corpus. Its categories were Halal knowledge, Halal process understanding, Halal compliance awareness and Halal integrity, together with the technology-related capabilities of traceability, digital quality management, automation and data analytics (Table 3).

3. **Mapping and classification.** Each original theme was mapped against the framework and classified using explicit rules. A theme was *retained* when the literature described the same competency in the Halal context without added Halal conditions; *contextualised* when the same competency was bounded by Halal compliance requirements; *expanded* when the Halal literature extended its scope; and

additional when a requirement appeared in the Halal literature but had no counterpart theme in the original data.

4. **Prioritisation.** Each competency was rated High (2), Medium (1) or Low (0) on three criteria: C1, centrality to Halal integrity in technology-enabled operations; C2, evidence of demand or skill gap in the stakeholder and job-market literature; and C3, convergence between the original themes and the Halal literature. Totals of 5–6 indicated core (Tier 1) competencies, 4 important (Tier 2) and 3 or below supporting (Tier 3) competencies.

5. **Synthesis.** The mapped and prioritised competencies were integrated into a conceptual framework. To explain the relationship between technology adoption, competencies and readiness, the evidence was traced study by study to see how each linked technology, people and outcomes.

Fit and limitations of secondary use

As in any secondary analysis, attention was paid to the fit between the original research question and the present one, and to the responsible re-use of data collected for a related purpose. The original data were not gathered in a Halal-specific setting, so the Halal requirements in the framework come from the literature rather than from the original participants. The ratings used for prioritisation are the authors' qualitative judgements against stated criteria. The mapping and the priorities are therefore interpretive and indicative, and the proposed validation in the Results and Discussion section addresses this limitation.

RESULTS AND DISCUSSION

Mapping the original themes to Halal requirements

The original study highlighted Industry 4.0 awareness, digital competencies, adaptability, problem-solving, innovation, organisational readiness, leadership and structured coaching and support (Kamarudin et al., 2025). Table 5 shows how general Industry 4.0 employability dimensions become Halal-specific dimensions, and Table 6 summarises the outcome of the mapping with its supporting evidence.

Table 5. Distinction between previous IR4.0 research and the new Halal dimension

Previous IR4.0 research	New Halal dimension
Digital competency	Digital + Halal competency
Technology readiness	Technology + Halal process readiness
Problem-solving	Halal-sensitive problem-solving
Innovation	Halal innovation capability
Adaptability	Adaptability within Halal requirements
Organisational compliance	Halal compliance awareness
General ethics	Halal integrity and ethical decision-making
Continuous learning	Integrated technology–Halal learning
Industry support	Halal ecosystem support and coaching

Table 6. Outcome of the mapping of Industry 4.0 themes against Halal requirements

Mapping outcome	Themes	Halal-context interpretation	Supporting evidence
Retained	Industry 4.0 awareness; leadership	Remain valid as enablers; leaders must link digital transformation with Halal integrity.	Albawardi et al. (2026); Hadis et al. (2025); Jayashree et al. (2022)

Contextualised	Digital competencies; organisational and technology readiness; adaptability; problem-solving	Same competency, now bounded by Halal requirements (digital + Halal competency; Halal-sensitive problem-solving).	Ahmad et al. (2024); Albawardi et al. (2026); Ellahi et al. (2025); Tee et al. (2024)
Expanded	Innovation; continuous learning; structured coaching and support	Wider scope: Halal innovation capability, integrated technology–Halal learning, and Halal ecosystem support.	Abidin et al. (2026); Hadis et al. (2025); Kudus et al. (2025); Yahya et al. (2023)
Additional	Halal knowledge; Halal process understanding; Halal compliance awareness; Halal integrity and ethical decision-making	No direct counterpart in the original themes; they derive from the Halal literature and complete the dual competency.	Abidin et al. (2026); Rosli et al. (2022); Tukiran et al. (2025); Ziegler et al. (2024)

The pattern in Table 6 is informative. Only awareness and leadership carry over unchanged. Most technical and cognitive competencies are contextualised, which means that they remain necessary but must be exercised within Halal boundaries. Four requirements are additional, and these are what the general employability literature cannot supply.

Priority competencies for the Halal industry

Table 7 applies the prioritisation criteria described in the Methodology. Four competencies emerge as core: Halal compliance awareness, Halal traceability and data integrity, digital and data analytics competency, and Halal-sensitive problem-solving. Five are important, and two are supporting.

The five competencies highlighted in the literature each find a place in this ordering. Halal compliance awareness is the foundation: job postings and programme standards place weight on specialised Halal knowledge (Abidin et al., 2026), and without it digital competence can compromise integrity. Traceability and data integrity rank equally high because traceability technologies are the main route to verification (Ellahi et al., 2025; Ziegler et al., 2024) and are already in use, with RFID the most advanced in Malaysian Halal food manufacturing (Musadik, 2024). A system can record a transaction, but a person must verify that the record is accurate and decide whether a doubtful input should be accepted, flagged or rejected. Data analytics is core because information and data literacy are the most demanded digital skills (Tee et al., 2024) and Halal manufacturing needs staff who can interpret dashboards and system alerts (Albawardi et al., 2026).

Digital Halal quality management and automation oversight are rated important rather than core because the evidence of present demand is thinner. Sensor-based monitoring, digital audit trails, digital twins and AI-supported processes are described as opportunities (Albawardi et al., 2026; Ellahi et al., 2025), but adoption in Malaysian Halal food manufacturing is still at an early stage for the more advanced technologies (Musadik, 2024). These competencies are therefore expected to rise in priority as adoption deepens, and the ranking should be revisited as evidence accumulates.

Table 7. Indicative prioritisation of competencies

Competency	C1	C2	C3	Score	Priority	Key evidence
Halal compliance awareness	H	H	M	5	Tier 1 (core)	Abidin et al. (2026); Rosli et al. (2022)
Halal traceability and data integrity	H	H	M	5	Tier 1 (core)	Ellahi et al. (2025); Hadis et al. (2025); Musadik (2024); Ziegler et al. (2024)
Digital and data analytics competency	M	H	H	5	Tier 1 (core)	Albawardi et al. (2026); Kamarudin et al. (2025); Tee et al. (2024)

Halal-sensitive problem-solving	H	H	H	6	Tier 1 (core)	Ellahi et al. (2025); Kamarudin et al. (2025); Tee et al. (2024)
Digital Halal quality management	H	M	M	4	Tier 2 (important)	Albawardi et al. (2026); Ellahi et al. (2025)
Halal-sensitive automation oversight	H	M	M	4	Tier 2 (important)	Albawardi et al. (2026); Ellahi et al. (2025); Musadik (2024)
Halal process understanding	H	M	M	4	Tier 2 (important)	Albawardi et al. (2026); Rosli et al. (2022)
Halal integrity and ethical decision-making	H	M	M	4	Tier 2 (important)	Ellahi et al. (2025); Ziegler et al. (2024)
Adaptability and continuous learning	M	M	H	4	Tier 2 (important)	Abidin et al. (2026); Hadis et al. (2025); Kamarudin et al. (2025)
Communication and collaboration	M	H	L	3	Tier 3 (supporting)	Tee et al. (2024)
Innovation capability	M	L	H	3	Tier 3 (supporting)	Ellahi et al. (2025); Kamarudin et al. (2025)

Note. C1 = centrality to Halal integrity; C2 = evidence of demand or skill gap; C3 = convergence between the original themes and the Halal literature; H = High (2), M = Medium (1), L = Low (0).

Dual competency in practice

In the general employability literature, digital competency refers to the ability to find, evaluate, create, communicate and protect information using digital tools (Tee et al., 2024). In the Halal industry this competency is necessary but not sufficient. A worker operating a traceability platform, interpreting sensor data or approving a digital record must also know what makes a product or process Halal, which control points matter, and when a deviation requires escalation. Ahmad et al. (2024) make a similar point when they argue that Halal executives need competencies that align Halal principles with technological advancement.

Problem-solving shows the same transformation. Tee et al. (2024) found it to be both the most demanded future digital skill and one of the largest graduate gaps. In Halal operations, problems are rarely only technical: a sensor alert in a cold chain, a discrepancy in a digital record or a supplier change may each carry Halal implications, so staff need problem-solving that treats Halal integrity as a boundary condition. Innovation and adaptability operate within similar limits. New technologies such as augmented reality for verification or digital twins for training (Ellahi et al., 2025) create room for creative applications, but those applications must stay compliant, and adaptability means adjusting to new tools while keeping Halal principles intact (Ahmad et al., 2024). Ethics, finally, takes on a distinctive character: Halal integrity is about trust, and consumers rely on the honesty of everyone along the supply chain, which technology can support but cannot replace (Ziegler et al., 2024).

Enablers: leadership, continuous learning and ecosystem support

Three enabling conditions run through the evidence. The first is leadership: management leadership was a significant factor in Industry 4.0 adoption (Jayashree et al., 2022), and top management support was positively associated with the intention to adopt Halal traceability systems (Hadis et al., 2025). The second is continuous learning. The negative association between employee training and adoption intention reported by Hadis et al. (2025) suggests that training, as currently experienced by SMEs, may not yet equip staff for Halal-oriented

digital systems, and Abidin et al. (2026) similarly call for practical, competency-based learning. Learning should therefore integrate technology and Halal content rather than teach them separately, and digital tools can help deliver it provided that innovation is balanced with Shariah compliance (Kudus et al., 2025). The third is ecosystem support: institutional support was positively associated with readiness (Wong & Kee, 2022), government support and competitor pressure with adoption intention (Hadis et al., 2025), institutional pressures shaped intention among Halal food SMEs (Yahya et al., 2023), and the original study highlighted structured coaching and support (Kamarudin et al., 2025).

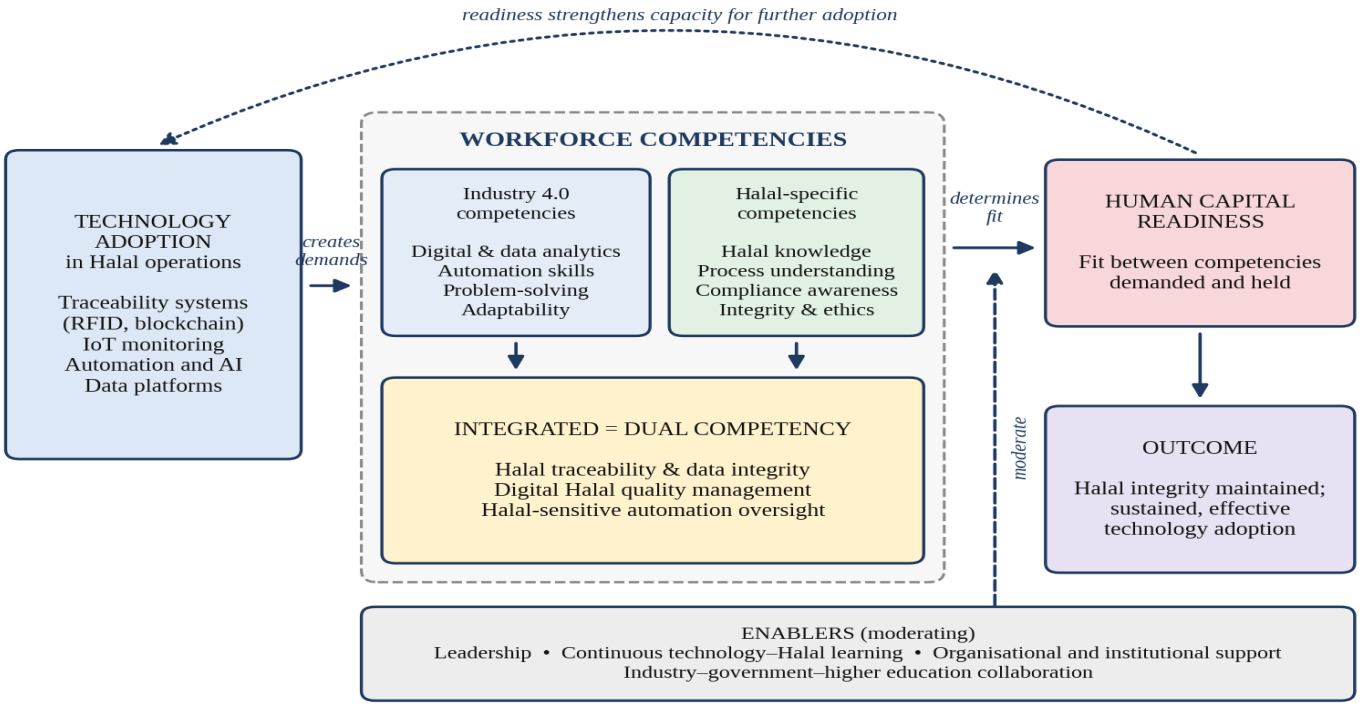
How technology adoption, competencies and human capital readiness are related

The evidence supports a four-link explanation, summarised in Figure 1. First, technology adoption changes the content of Halal work. When traceability records, environmental monitoring and verification move from paper and inspection to platforms and sensors, Halal-critical tasks become system-mediated and new tasks appear: interpreting dashboards, maintaining automated equipment and responding to alerts (Albawardi et al., 2026). Adoption therefore creates demand for the integrated competencies of Domain D.

Second, competencies determine whether adopted technology delivers Halal integrity. The technologies reviewed by Ellahi et al. (2025) and Ziegler et al. (2024) promise visibility, trust and accountability, but benefits depend on implementation, and Ellahi et al. note that practical evidence is limited. Hadis et al. (2025) found that perceived ease of use and employee training were negatively associated with the intention to adopt Halal traceability systems, which suggests that where staff are not equipped, complexity becomes a barrier. Albawardi et al. (2026) warn that employees without dual competence may resist new systems, use them incorrectly or revert to manual workarounds. Digital capability without Halal competence risks compliance errors, and Halal competence without digital capability risks non-use. Dual competency therefore mediates between technology adoption and the maintenance of Halal integrity.

Third, human capital readiness is best understood as the fit between the competencies that adopted technologies demand and the competencies the workforce holds. Fit can be assessed competency by competency using the priorities in Table 7, and a shortfall in a core competency creates the greatest risk to Halal integrity. Fourth, the relationship is reciprocal and conditional. Readiness increases an organisation's capacity to adopt further technology, since organisational capabilities and institutional support were positively associated with Industry 4.0 readiness (Wong & Kee, 2022) and IT resources, leadership, teamwork and external support influenced adoption (Jayashree et al., 2022). Competency development in turn depends on the enablers discussed above, which moderate how far training and coaching translate into readiness.

Figure 1. Conceptual framework of Halal–Industry 4.0 Human Capital Readiness



The framework yields five propositions for future testing:

- **P1:** Greater adoption of Industry 4.0 technologies in Halal operations increases the demand for integrated (Domain D) competencies.

- **P2:** Dual competency mediates the relationship between technology adoption and the maintenance of Halal integrity.

- **P3:** Human capital readiness increases with the fit between the competencies demanded by adopted technologies and those held by the workforce.

- **P4:** Shortfalls in core (Tier 1) competencies reduce readiness more than shortfalls in supporting (Tier 3) competencies.

- **P5:** Leadership, continuous technology–Halal learning, organisational support and industry–government–higher education collaboration strengthen the relationship between competency development and readiness.

Stakeholder evidence and proposed validation

As Table 4 shows, the present evidence base covers practitioners, entrepreneurs, agencies and academics directly through the original dataset, and covers Halal-certified businesses, educators and employees indirectly through the literature. The priorities in Table 7 should therefore be treated as hypotheses to be validated. A three-stage design is proposed. First, a Delphi study with Halal executives, certification personnel and regulators would test and rank the competencies in Table 3. Second, a survey of Halal-certified businesses and their employees would measure competency levels, technology adoption and readiness, so that propositions P1 to P5 can be tested, for instance through partial least squares structural equation modelling. Third, focus groups with educators, together with a curriculum audit, would examine whether Halal and technology programmes develop the core competencies.

Implications

For Halal organisations, especially SMEs, Halal and digital competence should be treated as joint hiring and development criteria. Development effort can be sequenced by priority, beginning with compliance awareness, traceability and data integrity, data analytics and Halal-sensitive problem-solving, supported by on-the-job coaching in which staff learn digital tools within real Halal workflows and leaders explicitly link digital transformation with Halal integrity. **For policymakers**, support schemes for Industry 4.0 adoption and for Halal development are usually separate; readiness assessments, incentives and coaching schemes that include Halal human capital indicators would reflect the dual nature of the challenge, and institutional and government support has been shown to matter for both readiness and adoption (Hadis et al., 2025; Wong & Kee, 2022). **For higher education institutions**, Halal studies programmes may add digital and data competencies, while technology and business programmes that feed into Halal-related industries may add modules on Halal requirements and integrity, delivered through practical training and competency-based learning (Abidin et al., 2026).

CONCLUSION

This paper has re-examined an earlier dataset on youth employability in the Industry 4.0 job market through the lens of the Malaysian Halal industry. Using Qualitative Secondary Analysis supported by framework synthesis, it found that the original themes are not discarded in the Halal context: some are retained, most are contextualised or expanded, and four Halal-specific requirements must be added. The competencies were defined and classified into four domains, and four were identified as core: Halal compliance awareness, Halal traceability and data integrity, digital and data analytics competency, and Halal-sensitive problem-solving. The paper further argued that technology adoption does not by itself deliver readiness. Adoption creates competency demands, dual competency determines whether Halal integrity is maintained, and leadership, continuous learning, organisational support and collaboration among industry, government and higher education institutions condition the result.

LIMITATIONS AND FUTURE RESEARCH

The study is conceptual and interpretive. It relies on a single earlier dataset that was not collected in a Halal-specific setting, on a purposive selection of recent literature concentrated on food and meat supply chains, and on qualitative ratings made by the authors. It does not yet include primary evidence from Halal-certified businesses, industry experts, educators and employees. Future research should therefore carry out the validation described above, extend the framework to other Halal sectors such as pharmaceuticals, cosmetics and logistics, and evaluate training and curriculum interventions that develop the core competencies.

ACKNOWLEDGEMENT

The authors would like to thank the Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka (UTeM), for providing the facilities and support necessary to conduct this study.

REFERENCES

1. Abidin, N. F. A. F., Tukiran, N. A., & Ahmad, A. N. (2026). Assessing the Supply and Demand of Skills and Knowledge in the Halal Profession in Malaysia. *Journal of Fatwa Management and Research, 31*(2), 86-116.
2. Ahmad, A. N., Jamil Nasri, N. S., Huda, F. H., Hashim, Y. Z. H. Y., Zulfigar, S. B., Samsudin, N., & Jamaludin, M. A. (2024). The fourth industrial revolution (IR4.0): aligning competencies for halal executives. In *Emerging technology and crisis management in the halal industry: Issues and recent developments* (pp. 251-271). Singapore: Springer Nature Singapore.
3. Albawardi, S. S. J. S., Rusli, N. S., & Alshami, S. A. (2026). Industry 4.0 adoption in Malaysian halal food manufacturing: Opportunities, challenges and future research for strengthening halal tourism competitiveness. *International Journal of Academic Research in Business and Social Sciences, 16*(2), 762-771.
4. Carroll, C., Booth, A., Leaviss, J., & Rick, J. (2013). "Best fit" framework synthesis: refining the method. *BMC medical research methodology, 13*(1), 37.
5. Ellahi, R. M., Wood, L. C., Khan, M., & Bekhit, A. E. D. A. (2025). Integrity challenges in halal meat supply chain: Potential industry 4.0 technologies as catalysts for resolution. *Foods, 14*(7), 1135.
6. Hadis, H., Tamin, M., Sarhadat, S. A., & Adis, A. A. A. (2025). Investigating SMEs' intention to adopt halal traceability system in Malaysia food and beverage supply chain: A TOE framework approach. *The Journal of Distribution Science, 23*(11), 29-39.
7. Heaton, J. (2004). *Reworking qualitative data*. SAGE Publications.
8. Heaton, J. (2008). Secondary analysis of qualitative data: An overview. *Historical Social Research/Historische Sozialforschung*, 33-45.
9. Jayashree, S., Reza, M. N. H., Malarvizhi, C. A. N., Gunasekaran, A., & Rauf, M. A. (2022). Testing an adoption model for Industry 4.0 and sustainability: A Malaysian scenario. *Sustainable production and consumption, 31*, 313-330.
10. Kamarudin, M. F., Noorzelan, M. R., Mustafa, N. A., & Rozaki, Z. (2025). Youth employability readiness and sustainability for the IR4.0 job market: A grounded theory. In *Integrating artificial intelligence, security for environmental and business sustainability: Volume 2* (pp. 151–160). Springer Nature Switzerland.
11. Kudus, N., Bin Ismail, I. A., Abu Hassan, M., Mohamed, S., & Abdullah, F. (2025). Digital transformation and halal human resource development: Leveraging technology for ethical workforce enhancement: A literature review. *International Journal of Academic Research in Business and Social Sciences, 15*(2), 1394-1404.
12. Musadik, S. H. S. A. (2024). Technology application in halal food manufacturing in Malaysia. In *Emerging technology and crisis management in the halal industry: Issues and recent developments* (pp. 187-200). Singapore: Springer Nature Singapore.
13. Rosli, N. M., N R, H., FH, A. F., Hashim, Y. Y., & Ahmad, A. N. (2022). A conceptual core competency model for halal executives in food manufacturing companies. *Journal of Halal Science and Technology, 1*(1), 1-14.

14. Saima, S. U., Firdaus, R. B. R., & Sarjiyanto. (2024). Challenges and ways forward for the Malaysian SMEs in the Halal food industry: a systematic review. *Potravinarstvo Slovak Journal of Food Sciences, 18*, 223-238.
15. Tee, P. K., Wong, L. C., Dada, M., Song, B. L., & Ng, C. P. (2024). Demand for digital skills, skill gaps and graduate employability: Evidence from employers in Malaysia. *F1000Research, 13*, 389.
16. Tukiran, N. A., Abidin, N. F. A. F., & Ahmad, A. N. (2025). Identifying Gaps In Halal Talent Development And Management In Malaysia: A Systematic Literature Review. *Al-Qanatir: International Journal of Islamic Studies, 34*(01), 78-81.
17. Wong, A. P. H., & Kee, D. M. H. (2022). Driving factors of Industry 4.0 readiness among manufacturing SMEs in Malaysia. *Information, 13*(12), 552.
18. Yahya, S., Kamaruzzaman, Z. A., & Mokhtar, M. (2023). SME's Behavioural Intention Towards IR 4.0 Technology in Malaysian Halal Food Industry. *European Proceedings of Social and Behavioural Sciences*.
19. Ziegler, Y., Uli, V., & Tatari, M. (2024). Leveraging blockchain technology for ensuring the integrity of halal supply chains: A systematic review. *Journal of halal quality and certification, 2*(1), 8-19.