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Industry 4.0 Readiness Assessment Using Weighted Sum Model for Malaysian Micro, Small and Medium Enterprises

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ABSTRACT

Industry 4.0 brings significant productivity gains and competitive advantages through the integration of the Internet of Things (IoT) and Smart Manufacturing. In Malaysia, micro, small and medium enterprises (MSMEs) account for approximately 97.4% of total business establishments, contributing substantially to national employment and GDP. However, many MSMEs still face many challenges and lack of direction toward industry 4.0. Existing frameworks, such as the Ministry of International Trade and Industry's (MITI) Industry4WRD are not specifically designed based on the challenges of MSMEs. To address this gap, this study develops the Industry 4.0 Readiness Assessment Model tailored for Malaysian MSMEs. The model organises readiness into five thrusts: Planning and Strategy, Finance, Technology, Skills, and Data Digitalisation and encompassing by thirteen specific dimensions. The Analytical Hierarchy Process (AHP) is used to determine the priority weight for each thrust and dimension, while the Weighted Sum Model (WSM) aggregates the self-assessment scores into an Industry 4.0 readiness score. The model was implemented and verified through a case study involving a Malaysian F&B manufacturing MSME. The analysis revealed that 'Planning and Strategy' and 'Finance' emerged as the most critical thrusts for MSME readiness. The case company achieved an overall readiness score of 2.16, corresponding to Level 2 (Beginner). This result demonstrates the model's ability to pinpoint specific gaps, particularly in automated infrastructure and data integration, providing a structured basis for prioritizing transformation initiatives. The developed assessment model offers a practical and systematic approach to help Malaysian MSMEs plan and implement Industry 4.0 transformation more effectively.

Keywords: Industry 4.0 Readiness; MSMEs; AHP; WSM; digital transformation; readiness assessment tool; Malaysia

INTRODUCTION

The Fourth Industrial Revolution, commonly referred to as Industry 4.0, marks a significant transformation in industrial operations through the integration of cyber-physical systems, the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and other advanced technologies (Abdullah & Al-Ahmari, 2025; Ghobakhloo et al. 2022). While the potential of Industry 4.0 has been well-recognised in enhancing the productivity of large-scale manufacturers, its impact on micro, small, and medium-sized enterprises (MSMEs) is more complex and often under-addressed, especially in emerging economies (Ansari et al. 2023). In the Malaysian context, MSMEs constitute over 97% of total business establishments; however, many still face structural, financial, and technological challenges in adapting to Industry 4.0 advancements (Shahzad et al. 2023; SME Corporation Malaysia, 2022).

In response, national strategies such as the Industry4WRD policy have been introduced to provide

structured pathways for digital transformation (Ministry of International Trade and Industry, 2018). However, these frameworks are often broad in scope and primarily tailored to medium and large enterprises, offering limited operational guidance for micro and small firms (Wong & Kee, 2022). This limitation is especially critical for smaller enterprises, which commonly encounter challenges related to limited resources, inadequate digital competencies, and constrained implementation capabilities (Techanamurthy et al. 2025). Consequently, there is a clear need for a more targeted, practical, and scalable readiness assessment model that aligns with the specific operational context of Malaysian MSMEs (Shahzad et al. 2023).

This paper presents an Industry 4.0 Readiness Assessment Model developed to address these identified gaps. In contrast to conventional maturity assessment frameworks, the proposed model adopts a layered evaluation structure that organizes readiness into five strategic thrusts (Aras & Büyüközkan, 2023; Hajoary et al. 2024). Each thrust is further refined into operationally distinct dimensions representing core competencies that are critical for digital readiness. This structured and detailed design enables a more context-sensitive and practical evaluation, aligning closely with the operational realities and implementation capacities of MSMEs (Abdullah & Al-Ahmari, 2025).

To ensure methodological rigour, the model applies the Analytical Hierarchy Process (AHP) to assign priority weights to each dimension, using expert judgments that align with national strategic priorities. The scoring mechanism is based on a structured computation method that converts qualitative responses into weighted quantitative scores using the Weighted Sum Model (WSM), which aggregates the values linearly across thrusts and dimensions (Ahmad & Hajeedar, 2021). The final output includes dimension-specific performance summaries and an overall readiness classification, categorized into five maturity stages: Beginner, Intermediate, Developing, Advanced, or Smart Factory.

The model has been validated through expert consultation and pilot testing involving actual MSME participants, ensuring that both its technical structure and practical usability are optimised (Rakiman et al. 2024). Additionally, empirical research shows that despite national programmes, Malaysian SMEs still face significant gaps in strategic planning, which hinder their ability to fully adopt advanced technologies (Techanamurthy et al. 2025).

This paper outlines the development, implementation, and verification of the proposed readiness assessment framework, with a focus on its theoretical foundations, computational mechanisms, and utility as a decision-support tool for digital transformation. The overarching aim is to bridge the gap between national policy frameworks and on-the-ground MSME implementation, while also equipping local enterprises with actionable, data-driven insights to embark on their Industry 4.0 journey with enhanced clarity and strategic direction (SME Corporation Malaysia, 2021).

METHODOLOGY

This study adopts a structured multi-criteria decision-making (MCDM) approach to develop an Industry 4.0 Readiness Assessment Model tailored for Malaysian MSMEs (Ahmad & Hajeedar, 2021). The methodology integrates the Analytical Hierarchy Process (AHP) for deriving priority weights and the Weighted Sum Model (WSM) for aggregating scores, ensuring both methodological robustness and practical usability (Ahmad & Hajeedar, 2021; Taherdoost & Madlan, 2023). Figure 1 shows the research methodology flowchart for developing and implementing the proposed Industry 4.0 Readiness Assessment Model.

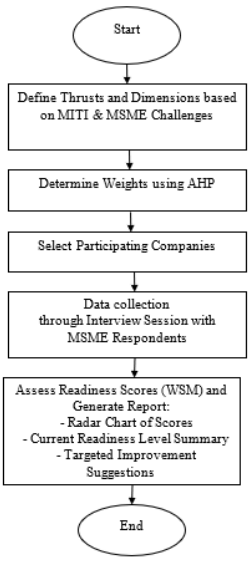

FIGURE 1. Research Methodology Flowchart for the MSME Industry 4.0 Readiness Assessment Model

5 THRUSTS AND 13 DIMENSIONS

The development of the Malaysian MSME Industry 4.0 Readiness Assessment Model adopts a structured Design for Six Sigma (DFSS) framework, utilizing the DMADV methodology (Define–Measure–Analyze–Design–Verify) to ensure that the model is systematic, quantifiable, and validated (Ahmad & Hajeedar, 2021). This approach incorporates insights from national policy documents, industrial best practices, and empirical studies related to

readiness measurement (Ministry of International Trade and Industry, 2018; Shahzad et al. 2023). The model identifies five core thrusts that represent the strategic domains influencing readiness: Planning and Strategy, Finance, Technology, Skills, and Data Digitalization (Aras & Büyüközkan, 2023; Hajoary et al. 2024b). These thrusts reflect the fundamental areas that determine an MSME's ability to initiate, manage, and sustain Industry 4.0 transformation initiatives (Ghobakhloo et al. 2022).

Within the Define and Measure phases, each thrust is further decomposed into clearly defined and quantifiable dimensions to enable detailed and practical assessment (Aras & Büyüközkan, 2023). For instance, the Planning and Strategy thrust includes dimensions such as Industry 4.0 Awareness, Leadership Commitment, Strategic Roadmap, and Adoption Plans (Wong & Kee, 2022). The Data Digitalization thrust encompasses Data Analysis, System Integration Processes, and Cybersecurity Measures, in line with recent studies that emphasize the importance of data integration and protection as critical enablers (Marolt et al. 2025; Abdullah & Al-Ahmari, 2025). Meanwhile, the Technology thrust covers both Hardware Infrastructure Technologies and Software Technologies, which are recognized as key determinants of readiness (Ansari et al. 2023; Tavana et al. 2023).

Meanwhile, the Skills thrust includes Digital Software Proficiency Skills and Hardware Operation and Maintenance Skills, which address the human capital requirements essential for effective digital adoption (Techanamurthy et al. 2025). The Finance thrust, on the other hand, focuses on Funding for Technology Adoption and Investment in Workforce Skills, both of which support the financial sustainability of MSME transformation efforts (Shahzad et al. 2023).

The selection and refinement of the thrusts and their corresponding dimensions are conducted during the Analyze and Design phases, ensuring alignment with national frameworks such as MITI's Industry4WRD (Ministry of International Trade and Industry, 2018), as well as internationally recognized SME maturity models (Hajoary et al. 2024a; Jamwal et al. 2025). This structured categorization provides a balanced emphasis on both strategic intent and operational capability (Aras & Büyüközkan, 2023). Furthermore, it forms the foundation for developing the model's diagnostic indicators, priority weighting, scoring logic, and the final Verify stage, which is validated through pilot testing and expert consultation (Rakiman et al. 2024). The newly developed MSME Industry 4.0 Readiness Criteria Model is shown in Figure 2, while the detailed thrusts and corresponding dimensions are outlined in Table 1.

FIGURE 2. Newly Developed MSME Industry 4.0 Readiness Criteria Model

TABLE 1. Key Components of the MSME Industry 4.0 Readiness Assessment Model

Thrusts	Dimensions
Planning and Strategy	Industry 4.0 Awareness
	Leadership
	Strategic Roadmap for Industry 4.0
	Industry 4.0 Adoption Plans
Data Digitalization	Data Analysis
	System Integration Processes
	Cybersecurity Measures
Technology	Software Technologies
	Hardware Infrastructure Technologies
Skills	Digital Software Proficiency Skills
	Hardware Operation and Maintenance Skills
Finance	Investment in Workforce Skills
	Funding for Technology Adoption

AHP PRIORITIZE VECTOR

After defining the thrusts and dimensions, the next phase uses the Analytical Hierarchy Process (AHP) to derive the relative priority weights for each component of the readiness model. AHP is selected because it allows systematic pairwise comparisons of multiple criteria and is well-established for multi-criteria decision-making in Industry 4.0 and SME contexts (Saaty, 2008; Taherdoost & Madlan, 2023). The structured comparison ensures that

each thrust and dimension contribute proportionately to the overall readiness score (Ahmad & Hajeedar, 2021).

In this study, pairwise comparison matrices are developed based on expert input from industry practitioners, policy makers, and academic researchers experienced in the digital transformation of MSMEs (Rakiman et al. 2024). Experts rate the relative importance of each element using the standard Saaty scale (1–9), which quantifies the preference strength between any two criteria (Saaty, 2008). The Priority Vector (weight) for each criterion is then calculated by normalizing the pairwise comparison matrix. The Priority Vector (weight) for each criterion is then calculated by normalizing the pairwise comparison matrix:

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{n} \quad (1)$$

where,
a_{ij} = value of element in row i and column *j*.

To verify the consistency of expert judgments, the Consistency Index (CI) and Consistency Ratio (CR) are computed (Ahmad & Hajeedar, 2021). The maximum eigenvalue (λ_{max}) is first determined:

$$\lambda_{max} = \frac{\sum_{i=1}^{n} (Aw)_i}{w_i}, \quad (2)$$

where A=pairwise comparison matrix,
w= Priority Vector

The Consistency Index (CI) is then:

$$CI = \frac{\lambda_{max} - n}{n - 1}, \quad (3)$$

where n= number of thrust or dimensions being compared
(also known as the order of the matrix)

and the Consistency Ratio (CR) is calculated as:

$$CR = \frac{CI}{RI}, \quad (4)$$

where RI is the Random Consistency Index. A CR value of less than 0.10 indicates acceptable consistency (Ahmad & Hajeedar, 2021; Taherdoost & Madlan, 2023).

The final normalized priority vectors obtained through AHP are embedded into the scoring system to ensure that readiness levels reflect the true strategic importance of each thrust and dimension (Senin et al. 2024).

COMPANY SELECTION

Once the thrusts, dimensions, and weighting structure are established, the next step involves selecting suitable companies to participate in the readiness assessment. The target group focuses on micro, small, and medium-sized manufacturing enterprises (MSMEs) in Malaysia, which make up over 97% of total business establishments (Shahzad et al. 2023; Wong & Kee, 2022).

A purposive sampling approach is used to ensure that the selected companies represent a range of industry sub-sectors and varying levels of digital adoption readiness (Yeong et al. 2022). Selection criteria include factors such as active business registration, operational status in the manufacturing sector, and the availability of key personnel who can provide informed responses (Marolt et al. 2025; Rakiman et al. 2024).

Invitations are distributed through industry associations and direct outreach. To ensure diverse insights, respondents include representatives from multiple organizational levels, aligning with practices recommended for MSME studies (Shahzad et al. 2023). This selection strategy ensures that the assessment captures a realistic snapshot of readiness levels and practical barriers faced by Malaysian MSMEs (Techanamurthy et al. 2025). To verify the Industry 4.0 Readiness Assessment, a food and beverage (F&B) company is selected.

INDUSTRY 4.0 READINESS SCORE CALCULATION

Data collection for this readiness assessment is carried out through a structured diagnostic survey supported by brief interview sessions with MSME respondents (Shahzad et al. 2023). The main instrument is a questionnaire consisting of multiple diagnostic questions developed based on the finalized thrusts and dimensions defined in the model (Aras & Büyüközkan, 2023; Wong & Kee, 2022). Each question is designed to measure a specific aspect of Industry 4.0 readiness and is rated using a standard five-point Likert scale, where higher scores indicate greater levels of awareness, implementation, or capability (Soomro et al. 2021).

To ensure data accuracy and context relevance, respondents are selected from various organizational levels, including top management, managers, supervisors, and technical staff (Rakiman et al. 2024; Yeong et al. 2022). Whenever necessary, short interview discussions are conducted during or after the survey session to clarify respondents' interpretations and ensure consistent understanding of the diagnostic items (Hajoary et al. 2024a). This mixed-method approach helps minimize

response bias and supports more realistic self-assessments (Shahzad et al. 2023).

The survey is administered both online and face-to-face, depending on the preference and accessibility of the participating companies. All responses are compiled and prepared for subsequent calculation using the Analytical Hierarchy Process (AHP) priority weights and the Weighted Sum Model (WSM) scoring logic (Ahmad & Hajeedar, 2021). This step ensures that the qualitative responses can be translated into a structured quantitative readiness index that accurately reflects the relative importance of each thrust and dimension (Taherdoost & Madlan, 2023).

The scoring mechanism is designed to translate qualitative responses gathered from MSME participants into a structured, quantitative readiness index. This approach ensures that performance across multiple thrusts and dimensions is measured consistently and objectively (Ahmad & Hajeedar, 2021; Ansari et al. 2023). Each diagnostic question is rated using a five-point Likert scale, and these scores are averaged to generate dimension-level scores (Marolt et al. 2025). The Analytical Hierarchy Process (AHP) priority weights are then applied to convert the average scores into weighted scores for each dimension (Sevinç et al. 2018).

The weighted scores for each dimension within a thrust are summed to calculate the thrust-level score. The final overall readiness index for an MSME is determined by aggregating the thrust scores across all five thrusts (Ahmad & Hajeedar, 2021). This process follows the standard Weighted Sum Model (WSM), which is widely applied in readiness and maturity assessment contexts (Hajoary et al. 2024b; Taherdoost & Madlan, 2023).

The resulting readiness index is then mapped onto five maturity levels adapted from recognized frameworks such as MITI's Industry4WRD and the FMM IMPULS Readiness Assessment (Ministry of International Trade and Industry, 2018; Wong & Kee, 2022). The levels used in this model are defined in Table 2, which outlines the scoring bands, maturity stages, and interpretations for MSME Industry 4.0 readiness classification.

TABLE 2. Key Components of the MSME Industry 4.0 Readiness Assessment Model

Readiness Score	Maturity Level	Interpretation
1.00-2.00	Level 1: Outsider	No significant Industry 4.0 adoption, relying on traditional processes.
2.01-3.00	Level 2: Beginner	Aware of Industry 4.0, but with minimal implementation and no clear strategy.
3.01-4.00	Level 3: Intermediate Adopter	Some Industry 4.0 adoption, but systems remain disconnected and limited.
4.01-4.50	Level 4: Advanced Adopter	Industry 4.0 technologies are integrated, but further optimization is needed.
4.51-5.00	Level 5: Expert	Fully transformed with seamless automation, AI, and smart manufacturing.

A score of 3.0 or above is defined as the minimum acceptable threshold for operational Industry 4.0 readiness. This benchmark indicates that the organization has moved beyond preliminary awareness and has begun implementing structured digital practices. Scores below this threshold signify foundational gaps that must be addressed before advanced technologies or transformation programmers can be successfully adopted (Ansari et al. 2023; Wong & Kee, 2022).

These maturity levels are not only useful for self-assessment but also serve external stakeholders such as policymakers, funding agencies, and industry consultants. Readiness assessment models provide a standardized framework for identifying capability gaps, qualifying organizations for support programmers, and benchmarking progress at both organizational and national levels (Hajoary et al. 2024b; Shahzad et al. 2023).

The model's scoring and classification system is integrated into an automated readiness assessment interface that enables consistent calculation and visualization of results through radar charts and tailored recommendations (Ahmad & Hajeedar, 2021; Abdullah & Al-Ahmari, 2025). This ensures usability without requiring advanced technical expertise. After all diagnostic responses are compiled, the scoring calculation uses the following logic which the general formula for WSM is expressed as:

$$S_i = \sum_{j=1}^{n} w_j \cdot x_{ij} \quad (5)$$

S_i is the overall score of i -th MSME.
x_{ij} represents the performance score of the i-th MSME with respect to the j -th criterion.
w_i is the weight of the j -th criterion as determined by AHP.

However, in this study, the readiness evaluation involves a two-layer AHP structure, consisting of main criteria and sub-criteria under each main criterion. To reflect this hierarchical weighting structure, the WSM formula is expanded as follows:

Step 1: Sub-criteria Scoring (Inner Layer)

For each main criterion i, there are m_i sub-criteria. The local readiness score for the main criterion i can be calculated as:

$$S_i = \sum_{j=1}^{m_i} w_{ij} \cdot x_{ij} \quad (6)$$

where:
w_{ij} is the local weight of the sub-criterion j under the main criterion i,
x_{ij} is the average performance score for the sub-criterion j.

If each sub-criterion score x_{ij} is derived from multiple individual assessments r_{ijk} (for instance, several respondents or measured indicators), it can be averaged as:

$$x_{ij} = \frac{1}{p_{ij}} \sum_{k=1}^{p_{ij}} r_{ijk} \quad (7)$$

where p_{ij} denotes the number of responses or measurement items contributing to that sub-criterion.

Step 2: Main Criteria Scoring (Outer Layer)

The overall readiness score R is then computed as a weighted combination of all main criteria, using their global weights W_i obtained from the outer-level AHP:

$$R = \sum_{i=1}^{n} W_i \, S_i \quad (8)$$

Substituting S_i from the previous step, the complete double-layer WSM formula is obtained. The overall Industry 4.0 Readiness Level (R) for an organization can be determined through a multi-level weighted aggregation of the criteria, sub-criteria, and indicator items using the MSME Industry 4.0 Readiness Assessment Model. The formulation of the model is expressed as follows:

$$R = \sum_{i=1}^{n} W_i \left(\sum_{j=1}^{m_i} w_{ij} \left(\frac{\sum_{k=1}^{p_{ij}} r_{ijk}}{p_{ij}} \right) \right) \quad (9)$$

where:
R = Overall Industry 4.0 Readiness Level
n = number of main dimensions (in this case, n = 5: Planning and Strategy, Finance, Technology, Skills, and Data Digitalization)
m_i = number of sub-criteria under dimension i
p_{ij} = number of items under sub-criterion j of dimension i
r_{ijk} = score assigned to item k under sub-criterion j of dimension i (ranging from 1 to 5)
w_{ij} = weight assigned to sub-criterion j within dimension i
w_i = weight assigned to dimension i

The model calculates the score as each MSME's performance scores are raised to its corresponding weight multiplied. Up to here, the evaluation weight had been mostly confined to the characteristic importance (taking AHP into account) and performance of MSME in terms of these characteristics. In this method, the cumulative readiness score is calculated as the sum of products of normalized scores for each criterion and their weights. The WSM is relevant to this research as the readiness assessment questions are collected on a five-point Likert scale (1–5), so all criteria can be comparable, and therefore they can all be aggregated meaningfully as a weighted sum. Calculate the final score of Industry 4.0 preparedness for each MSME, taking AHP-derived weights. In this example, the scores of each criterion (e.g., Technology, Strategy) are raised to the power of their weights, respectively.

This linear aggregation ensures that each thrust contributes proportionately to the final score, reflecting the relative importance established through expert judgment (Ahmad & Hajeedar, 2021; Sevinç et al. 2018). The resulting readiness index is then mapped to the five-level maturity classification to provide clear benchmarks for MSMEs to understand their current position and plan targeted improvements (Jamwal et al. 2025; Techanamurthy et al. 2025). In addition to assessing desirability per thrust, the approach also computes an aggregated readiness score, reflecting how ready an organization is in its Industry 4.0 transformation journey at this moment, by comparing a weighted sum of the level achieved on each of the individual thrusts. This overall composite score is intended to provide a summary of the company's performance in an easily digestible way, suitable for benchmarking and trend analysis.

INDUSTRY VERIFICATION

The final phase of this study focuses on verifying the Industry 4.0 Readiness Assessment Model to ensure its technical robustness, practical relevance, and overall reliability. This step aligns with the Verify stage in the DMADV methodology, confirming that the model achieves its intended objectives (Ahmad & Hajeedar, 2021; Aras & Büyüközkan, 2023).

The validation process begins with expert consultation involving industry practitioners, SME development consultants, and academic researchers specializing in digital transformation and readiness assessment (Rakiman et al. 2024; Shahzad et al. 2023). Experts provide feedback on the clarity, practicality, and contextual fit of the thrusts, dimensions, diagnostic indicators, and scoring structure. Adjustments are made to refine the questionnaire wording and dimension weightings based on consensus (Ansari et al. 2023; Hajoary et al. 2024a).

To further strengthen the tool's reliability, the verification stage includes formula integrity checks and consistency testing for the Analytical Hierarchy Process (AHP) and Weighted Sum Model (WSM) calculations (Ahmad & Hajeedar, 2021; Taherdoost & Madlan, 2023). Sensitivity analysis is also performed to assess the impact of possible variations in respondent scores and weighting scenarios (Ayan et al. 2023; Tavana et al. 2023). This step ensures that the model remains stable and credible even when applied across different company profiles and data completeness levels.

A pilot implementation is carried out with selected MSME participants representing diverse manufacturing sub-sectors and readiness stages (Shahzad et al. 2023). Feedback from pilot users confirms that the model is easy to understand, user-friendly, and produces actionable insights for improvement planning (Techanamurthy et al. 2025; Wong & Kee, 2022).

Overall, this comprehensive validation and verification process provides confidence that the proposed Industry 4.0 Readiness Assessment Model is technically sound, policy-aligned, and suitable for real-world application in the Malaysian MSME context (Rakiman et al. 2024; Techanamurthy et al. 2025; Wong & Kee, 2022).

RESULTS AND DISCUSSION

To evaluate the usability and scoring accuracy of the proposed readiness assessment model, a full pilot test was conducted with a participating Food and Beverage MSME operating in the manufacturing sector. The organization completed a 20-item self-assessment based on the model's defined dimensions. The structured scoring system then automatically computed dimension-level scores, weighted thrust-level scores, and an overall readiness index.

The resulting scores are summarized in Table 3, which shows how each dimension contributes to its respective thrust and how the final readiness score is computed using the Weighted Sum Model (WSM) with AHP-derived weights

TABLE 3. Readiness Scores Thrust and Dimension

Thrust	Dimension	Company Score	AHP Weight	Weighted Score
Planning & Strategy (Total: 1.1356)	Industry 4.0 Awareness	2.50	0.5359	1.3398
	Leadership Commitment	3.00	0.2291	0.6873
	Strategic Roadmap for Industry 4.0	2.00	0.1575	0.3150
	Industry 4.0 Adoption Plans	3.33	0.0775	0.2583
Finance (Total: 0.58725)	Funding for Technologies Adoption	2.50	0.75	1.8750
	Investment in Workforce Skills	1.50	0.25	0.3750
Technology (Total: 0.2342)	Hardware Infrastructure Technologies	1.50	0.75	1.1250
	Software Technologies	1.33	0.25	0.3333
Skills (Total: 0.0954)	Digital Software Proficiency Skills	1.00	0.6667	0.6667
	Hardware Operation and Maintenance Skills	1.00	0.3333	0.3333
Data Digitalization (Total: 0.1063)	Data Analysis and Insights	3.33	0.5571	1.8571
	System Integration Processes	1.00	0.3202	0.3202
	Cybersecurity	1.00	0.1226	0.1226
Overall Readiness Score		2.16		

CALCULATION PROCESS

To ensure transparency and replicability, the Readiness Assessment Model calculations are outlined:

$$
\begin{aligned}
R \quad = 0.4367 & \left[\begin{array}{c} 0.5359\left(\frac{5+3+1+1}{4}\right) + 0.2291\left(\frac{5+3+1}{3}\right) \\ +0.1575\left(\frac{3+2+1}{3}\right) + 0.0775\left(\frac{5+3+2}{3}\right) \end{array} \right] \\
& +0.2610\left[0.7500\left(\frac{3+2}{2}\right) + 0.2500\left(\frac{2+1}{2}\right)\right] \\
& +0.1606\left[0.7500\left(\frac{2+1}{2}\right) + 0.2500\left(\frac{2+1+1}{3}\right)\right] \\
& +0.0954\left[0.6667\left(\frac{1+1+1+1}{4}\right) + 0.3333\left(\frac{1+1}{2}\right)\right] \\
& +0.0462\left[\begin{array}{c} 0.5571\left(\frac{4+3+3}{3}\right) + 0.3202\left(\frac{1+1}{2}\right) \\ +0.1226\left(\frac{1+1}{2}\right) \end{array} \right]
\end{aligned}
$$

Now sum them up:

R=1.1345+0.5873+0.2343+0.0954+0.1060=2.1587

So, when the actual company scores are substituted directly into your full formula, the overall Industry 4.0 readiness level = 2.1587 (≈ 2.16) on a 5-point scale. With an overall readiness score of 2.16, the MSME falls under the Beginner level on the readiness maturity scale, reflecting sporadic digital efforts with limited systemic alignment or technical capacity.

The overall readiness score of 2.16, which classifies the MSME at the Beginner level, was further verified through a follow-up session with the company's management. This qualitative validation confirmed that the result is highly consistent with the company's current operational reality, characterized by sporadic digital efforts and a lack of systemic technical alignment. This alignment between the model's output and the actual shop-floor condition proves the reliability and practical validity of the assessment tool.

RADAR CHART ANALYSIS

To visualize the readiness performance across the five strategic thrusts, the model includes a radar chart that maps the thrust-level scores calculated during the assessment process.

Figure 3 illustrates the Industry 4.0 readiness profile of the participating MSME across the five thrusts: Planning and Strategy, Finance, Technology, Skills, and Data Digitalization. Based on the radar chart, all thrusts scored below the recommended minimum threshold of 3.0, which is required to achieve the "Developing" maturity level. This indicates that the organization is still at an early stage of digital transformation and requires improvement in multiple areas.

FIGURE 3. Radar Chart of MSME Company Readiness by Thrust

ANALYSIS AND INTERPRETATION

Among the five thrusts, Planning and Strategy (2.60) and Finance (2.25) recorded the highest scores. These results suggest that the MSME has begun building awareness of Industry 4.0 and has started to allocate resources toward digital initiatives. These two thrusts serve as foundational enablers of transformation and should be the primary focus during the early phases of improvement.

Data Digitalization (2.30) shows moderate progress, though its impact may be limited by weaknesses in Technology (1.46) and Skills (1.00). These two thrusts represent operational gaps, particularly in the areas of digital infrastructure and workforce competency.

The radar chart highlights the imbalance between strategic readiness and implementation capacity. To move toward a more sustainable and structured transformation, a phased improvement strategy is recommended:

1. Begin by strengthening core strategic and financial capabilities, focusing on Planning and Strategy and Finance.
2. Gradually address the remaining thrusts, particularly Technology and Skills, followed by the enhancement of Data Digitalization efforts.

This sequential approach ensures that future investments are supported by strong leadership, sufficient

resources, and a clear strategic direction, which collectively increase the likelihood of successful Industry 4.0 adoption.

This bar chart in Figure 4 presents the weighted readiness scores for each of the five strategic thrusts assessed in the participating MSME. The orange horizontal line at score 3.0 represents the minimum threshold for "Developing" readiness, as defined in the assessment model.

All thrusts scored below this benchmark, indicating that the organization has not yet achieved foundational digital maturity in any area. Planning and Strategy (2.60), Finance (2.25), and Data Digitalization (2.30) show relatively better progress, while Technology (1.46) and Skills (1.00) remain significantly underdeveloped.

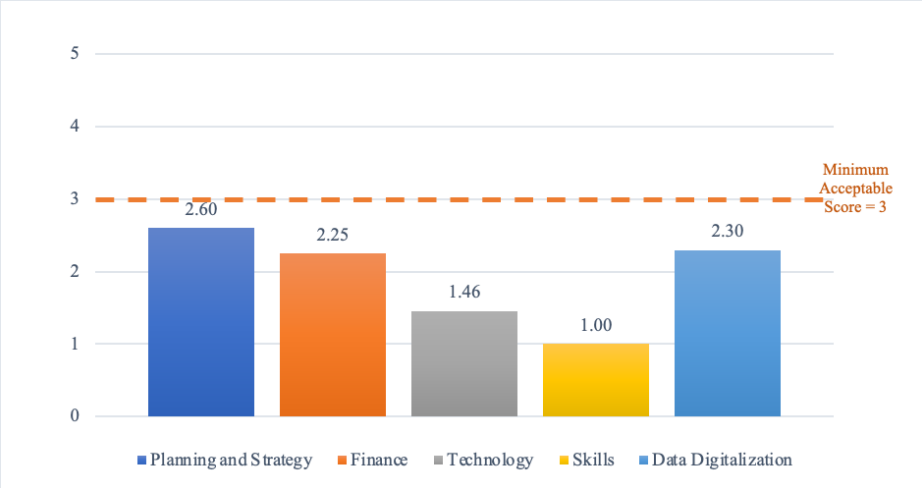

FIGURE 4. Bar Chart of Weighted Readiness Scores across Thrusts

This visual reinforces the need for a structured and phased approach to improvement, beginning with strengthening leadership, financial capability, and awareness, followed by investment in workforce upskilling and digital infrastructure. To provide a more detailed view of the most influential thrust, Figure 5 focuses on the internal performance of Planning and Strategy.

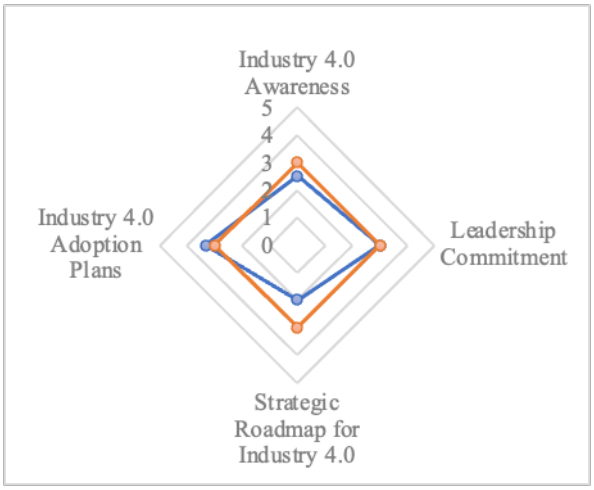

FIGURE 5. Radar Chart of MSME Company Readiness: Planning and Strategy Thrust

The radar chart shows that the MSME demonstrates relatively strong performance in Leadership and Industry 4.0 Adoption Plans, with respective scores of 3.00 and 3.33. These results reflect clear top-level support and early-stage efforts to initiate digital transformation within the organization.

In contrast, the dimension Strategic Roadmap for Industry 4.0 scored only 2.00. This suggests that although

there is intent to move forward with transformation, the organization lacks a structured plan to guide the implementation process. Additionally, Industry 4.0 Awareness recorded a moderate score of 2.50, indicating that understanding of digital transformation principles may not yet be widespread across all levels of the organization.

Overall, the chart reinforces the importance of translating leadership commitment into clearly defined strategies and structured action plans. Strong leadership and intent must be supported by internal communication and organizational alignment to ensure that digital transformation efforts are effectively executed and sustained. Table 4 presents the individual scores for each sub-dimension under the Planning and Strategy thrust.

TABLE 4. Sub-Dimension Scores within the Planning and Strategy Thrust

Dimension	Sub-Dimension (Item)	Score
Industry 4.0 Awareness	Awareness among top management about Industry 4.0 trends and impact on the organization	5
	Awareness among managers about Industry 4.0 and its integration into production processes	3
	Awareness among supervisors about how Industry 4.0 affects workflow and operational efficiency	1
	Awareness among operators about how Industry 4.0 can impact daily tasks	1
	Dimension Score	1.3398
Strategic Roadmap	Details in the organization's outlined steps, timelines, and milestones for Industry 4.0 implementation	3
	Alignment between Industry 4.0 strategic goals and departmental objectives	2
	Understanding among supervisors regarding role in the Industry 4.0 roadmap	1
	Dimension Score	0.3150

Calculation of Dimension Score

The score for each dimension (e.g., *Industry 4.0 Awareness*) is calculated in two main stages to integrate raw assessment results with expert-determined priority weights.

Step 1: Calculation of the Dimension Average Score

Each dimension is assessed using several items or sub-dimensions. For example, awareness may be evaluated across different organizational levels. The dimension's average score is obtained by summing all item scores and dividing by the total number of items.

From the assessment data:
- Item Scores: 5, 3, 1, and 1
- Number of Items (n): 4

$$\text{Average Score} = \frac{5+3+1+1}{4} = 2.50$$

This value (2.50) is reported as the Company Score for the respective dimension in the summary table.

Step 2: Calculation of the Dimension Score

To account for the strategic importance of each dimension, the average score is multiplied by its corresponding AHP priority weight. These weights are derived using the Analytical Hierarchy Process (AHP) based on expert evaluation.

Using the values from the results table:
- Average Company Score: 2.50
- AHP Weight: 0.5359

$$\text{Dimension Score} = 2.50 \times 0.5359 = \mathbf{1.3398}$$

Mathematical Summary

The overall calculation for each dimension can be expressed as:

$$\text{Dimension Score} = \left(\frac{\sum \text{Sub-dimension Scores}}{\text{Total Sub-dimensions}}\right) \times \text{AHP Priority Weight}$$

This approach ensures that the final readiness index is not a simple average, but a weighted representation that

emphasizes high-impact dimensions as identified by industry experts.

The sub-dimension analysis reveals important insights about the organization's strategic readiness posture:

1. Industry 4.0 Awareness received the highest dimension score (1.3398), primarily driven by strong awareness among top management (score = 5). However, awareness drops sharply at lower organizational levels, particularly among supervisors and operators (scores = 1), indicating a disconnect in knowledge dissemination throughout the company.
2. Suggestion for Improvement: Conduct monthly Industry 4.0 awareness workshops for managers, supervisors, and operators to ensure consistent knowledge transfer across all levels. Develop internal communication channels such as newsletters, briefings, or knowledge-sharing sessions to reinforce understanding and commitment.
3. Strategic Roadmap for Industry 4.0 scored low (0.3150), reflecting a general lack of structured planning, milestone definition, and role clarity. This dimension highlights a key gap between intention and execution.
4. Suggestion for Improvement: Develop a clear short-term and long-term Industry 4.0 strategic roadmap with specific milestones, responsibilities, and timelines. Establish a cross-functional task force to oversee the roadmap implementation and regularly review progress.

In summary, the results for Industry 4.0 Awareness and the Strategic Roadmap dimensions suggest that while strategic intent and top-level awareness are present, there is insufficient alignment, communication, and operationalisation across departments and levels.

CONCLUSION

In this paper, the Industry 4.0 readiness assessment model was developed for Malaysian MSMEs using the Analytical Hierarchy Process (AHP) to derive expert-based weights and the Weighted Sum Model (WSM) to compute readiness scores across five strategic thrusts. The pilot results revealed a mismatch between strategic awareness and implementation capability, with notable weaknesses in the Skills and Technology thrusts that require immediate improvement through targeted training and gradual technology adoption. The participating organization reviewed and accepted the model's findings, confirming its value as a diagnostic tool for identifying gaps and guiding structured improvement. These outcomes support the model's potential as a practical decision-making reference for MSMEs seeking to plan and implement effective digital transformation strategies.

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DECLARATION OF COMPETING INTEREST

None.

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